7610–66–129–9740
Notified in DI(A) ADMIN 20 Series for 1990

RESTRICTED
The information given in this document is not to be communicated, either directly or indirectly, to the Press or to any person not authorised to receive it.

AUSTRALIAN ARMY

MANUAL OF LAND WARFARE

PART TWO

SIGNALS

VOLUME 4 PAMPHLET No 3

TACTICAL HIGH FREQUENCY RADIO HANDBOOK

1987

AUSTRALIAN ARMY

MANUAL OF LAND WARFARE

PART TWO

SIGNALS

VOLUME 4

COMMUNICATIONS HANDBOOKS

PAMPHLET No 3

TACTICAL HIGH FREQUENCY RADIO HANDBOOK

1987

Headquarters Training Command
13 July 1987

Authorised for issue.

(R. S. BUCHAN)
Major General
General Officer Commanding

7610–66–129–9740

Notified in DI(A) ADMIN 20 series for 1987

CONDITIONS OF RELEASE

1. This document contains Australian Defence information. All Defence information, whether classified or not, is protected from unauthorised disclosure under the *Crimes Act 1914 (Commonwealth)*. Defence information may only be released in accordance with *SECMAN 4* and/or DI(G) OPS 13-4 as appropriate.

2. When this information is supplied to Commonwealth or foreign governments, the recipient is to ensure that it will:

a. be safeguarded under rules designed to give it the equivalent standard of security to that maintained for it by Australia;

b. not be released to a third country without Australian consent;

c. not be used for other than military purposes;

d. not be divulged to a non-Defence organisation unless that organisation is sponsored and cleared by an accepted Defence organisation ('sponsoring' means giving an assurance that the organisation has a need to know for Defence purposes; 'clearing' means guaranteeing for security); and

e. not be downgraded or declassified without Australian Government approval.

Released to: .....

Released by: .....
(Signature)

.....
(Appointment)

Date Released: .....

© This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without written permission from Doctrine Production, Force Development Group, Combined Arms Training and Development Centre, Tobruk Barracks, PUCKAPUNYAL VIC 3662.

**Australian Army Manual of Land Warfare, Part Two, Signals,
Volume 4, Pamphlet No 3, Tactical High Frequency Radio Handbook, 1987**

Doctrine Production, Force Development Group, Combined Arms Training and Development Centre is responsible for the management and sponsorship of this pamphlet. The doctrine contained herein was approved on 13 July 1987.

AMENDMENT CERTIFICATE

1. Proposals for amendments or additions to the text of this pamphlet should be made through normal channels to the sponsor. To facilitate this, there are amendment proposal forms at the back of this publication.

2. It is certified that the amendments promulgated in the undermentioned amendment lists have been made in this pamphlet.

Amendment List		*Amended By (Printed Name and Initials)*	*Date of Amending*
Number	*Date*		
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			

DISTRIBUTION

Australian Army (less RA Sigs units)	Scale A
RA Sigs Units	Scale C

Training Quantities:

7 Signal Regiment	50
Royal Military College	20
Army Apprentice School	10
Armoured Centre	10
School of Artillery	10
School of Military Engineering	10
School of Military Survey	5
School of Signals	50
Infantry Centre	25
School of Army Aviation	5
School of Military Intelligence	5
Army School of Transport	10
Army Maritime School	5
School of Army Health	5
RAAOC Centre	5
RAEME Training Centre	5
Army School of Catering	2
School of Military Police	5
1 Training Group	20
2 Training Group	20
3 Training Group	20
4 Training Group	10
5 Training Group	10
6 Training Group	10
11 Training Group	5

PREFACE

Aim

1. The aim of this pamphlet is to provide information on the operation of high frequency radio communications.

Level

2. This handbook is intended for use by troop commanders and detachment commanders involved in the tactical planning and use of high frequency (HF) radio. It is not intended that this handbook be used as a source document but rather, as an aid to the more efficient use of the HF band.

3. This handbook is one of a series of Communications Handbooks, and should be used in conjunction with the other publications in the series.

Scope

4. This pamphlet provides doctrine on radio communications operating at frequencies in the range 3 MHz to 30 MHz.

5. This pamphlet provides information on the theory of high frequency radio communications for all RA Sigs personnel. It is designed to be used by tactical and training units to detail the tenets of operation and practical planning tenets.

CONTENTS

		Page
Title Page		i
Conditions of Release		ii
Amendment Certificate		iii
Distribution		iv
Preface		v
Contents		vii
Glossary		xiii
Abbreviations		xix

Section		Paragraph
	CHAPTER 1. FUNDAMENTAL CONSIDERATIONS	
1–1	Introduction	101
	Radio Waves	101
	Frequency Spectrum	102
1–2	Fading	104
	General	104
	CHAPTER 2. RADIO NOISE	
2–1	Types and Effects of Radio Noise	201
	General	201
	Atmospheric Noise	203
	Man-made Noise	205
	Receiver and Transmitter Noise	207
	CHAPTER 3. GROUND WAVE PROPAGATION	
3–1	Ground Waves	301
	Introduction	301
	The Surface Wave	302
	The Tilting Effect	304
	The Space Wave	305
3–2	Planning and Propagation of Ground Waves	390
	Ground Wave Planning	309
	Surface Wave Propagation	311
	Surface Wave Planning	312

Section *Paragraph*

CHAPTER 4. THE IONOSPHERE

4–1 The Ionosphere 401
General 401
The Ionosphere 402
4–2 Ionospheric Characteristics, Sky Wave Propagation 406
Critical Frequency 406
Critical Angle 408
Virtual Height 409
4–3 Regular Ionospheric Variations 410
General 410
Diurnal Variation 411
Seasonal Variation 412
Eleven-year Cycle 413
Twenty-seven-day Variation 414
4–4 Irregular Ionospheric Variations 415
General 415
Sporadic E Layer 416
SID (Dellingar Fade) 417
Ionospheric Storms 418
Absorption Limiting Frequency (ALF) 419
Optimum Working Frequency (OWF) (Optimum Traffic Frequency (FOT)) 421
Annex:
A. Irregular Variations of Ionosphere

CHAPTER 5. PREDICTION PUBLICATIONS AND CHARTS

5–1 Introduction 501
5–2 Frequency Predictions 507
General 507
GRAFEX Predictions 510
Using GRAFEX Predictions 515
5–3 Path-loss Predictions 522

Section *Paragraph*

5–4 Disturbance Warnings 527
General 527
Disturbances and Effects 529
The Warnings 532
Distribution of Warnings 534
Coping with Disturbances 535

Annex:
A. Typical Disturbance Warning

CHAPTER 6. HF FREQUENCY ASSIGNMENT

6–1 Tenets of Frequency Management 601
Introduction 601
RF Management 603
RF Allocation 604
RF Assignment 605

6–2 Frequency Sharing 606
The Regional System 607
The List System 610
Frequency Assignment at HF 616
Mutual Interference 619
Intermodulation 621
Interference Charts 624
Frequency Assignment for Tactical Radio Nets 627

Annexes:
A. Example of a Mutual Interference Chart for HF Links
B. Frequency Assignment Matrix

CHAPTER 7. PRACTICAL ANTENNAS

7–1 Introduction 701

7–2 Basic Field Antennas 703
Vertical Whip/Wire Antennas 703
Sloping Whip/Wire Antennas 710
The Inverted ‘L’ Antenna 713
The ‘T’ Antenna 717
The End-fed Antenna 719
Horizontal Half Wave Dipoles 722
Vertical Half Rhombic/Inverted Vee 723
Ground Antenna 725
Guide to Selection of Field Antennas 727
Formulas for Construction of Field Antennas 728
Summary of Field Antennas 729

Section *Paragraph*

CHAPTER 8. EARTHING TECHNIQUES

8–1 Introduction 801
8–2 Basic Earthing Techniques 808
Grounding Systems 808
Installation 815
Underground Objects 819
Ground Plates 821
Soil Conditions 823
Use of Multimeter 826
Safety 827

ILLUSTRATIONS

Figure *Page*

3–1 Surface Wave 3 – 1
3–2 Tilting Effect 3 – 2
3–3 Direct and Reflected Rays 3 – 3
3–4 Comparison of Wave Fronts of Direct and Reflected Waves 3 – 4
4–1 Average Layer Distribution of Ionosphere 4 – 2
4–2 Sky Wave Propagation 4 – 4
4–3 Virtual Height 4 – 5
4–4 Typical Diurnal Variation of Ionospheric Layers 4 – 6
6–1 Frequency Assignment Matrix 6B – 1
7–1 Average Efficiencies of 4.5 and 1.2 m Whip Antennas in the 2 to 30 MHz Band 7 – 2
7–2 The Vertical Quarter Wave Antenna Constructed of Wire Using Two Trees for Support 7 – 3
7–3 The Sloping Whip/Wire Antenna 7 – 4
7–4 The Inverted ‘L’ Antenna 7 – 5
7–5 The ‘T’ Antenna 7 – 6
7–6 The 3/4 Wavelength End-fed Antenna 7 – 7
7–7 The Sloping End-fed Antenna 7 – 8
7–8 The Half Wave Dipole 7 – 9
7–9 The Inverted ‘V’ Antenna 7 – 10
7–10 The Ground Antenna 7 – 11
8–1 Four Types of Ground Clamps 8 – 3
8–2 Removal Method 8 – 5
8–3 Ground Plate 8 – 6

Table *Page*

1–1	Radio Frequency Bands	1 – 1
2–1	Noise Sources	2 – 2
3–1	Conductivity Comparison Table	3 – 2
4–1	Irregular Variations of Ionosphere	4A – 1
5–1	GRAFEX Prediction Format	5 – 5
5–2	Frequency Selection URRL Form	5 – 7
5–3	Path-loss Predictions (in Decibels) with Probability Decile Ranges and Optimum Working Frequencies (MHz)	5 – 9
5–4	Noise/Path-loss Predictions with Decile Ranges and Optimum Working Frequencies (MHz)	5 – 10
5–5	RPC for AN/GRC 106 and PRC F1	5 – 11
6–1	Example of a Mutual Interference Chart for HF Links	6A – 1
7–1	Guide to Field Antenna Selection	7 – 12

GLOSSARY

The terms listed below are used in this pamphlet. The authority for each definition is shown in brackets. Where a definition is shown in italics, that definition, though commonly used by RA Sigs, has not been formally accepted for Joint Services use. The sources listed in this glossary are as follows:

a. *ACP 167. Allied Communications Publication, Glossary of Communications-Electronic Terms, December 1974.*

b. *QSTAG 595. Quadripartite Standardisation Agreement 595, Military Communications Systems, Standards, Terms and Definitions.*

c. *JSP(AS) 540. Joint Services Publication (Australia), Joint Tactical Communications System Engineering.*

Absorption. *In the transmission of electrical signals such as electromagnetic waves, the conversion of transmitted energy into heat or other forms of energy. (QSTAG 595)*

Absorption Limiting Frequency (ALF). In sky wave propagation, the predicted minimum useful frequency which will sustain transmission between two points at a particular hour for 50% of the days of the month. The limiting factor is due to absorption in the non-refracting ionospheric layers, typically the D or E layer. *(JSP(AS)540)*

Atmospheric Noise. *Radio noise caused by natural atmospheric processes, primarily lightning discharges in thunderstorms. (QSTAG 595)*

Attenuation. *Decrease in the intensity of a signal, beam, or wave as a result of absorption of energy and of scattering out of the path of a detector but not including the reduction due to geometric spreading, that is, the inverse square of distance effect. (QSTAG 595)*

Balun. *A radio frequency (RF) balancing network for coupling between balanced and unbalanced devices, normally used between equipment and transmission lines or transmission lines and antennas. (QSTAG 595)*

Critical Angle. *The maximum angle at which a radio wave may be emitted from an antenna and still be returned to earth by refraction in the ionosphere.*

Critical Frequency. *In radio propagation, by way of the ionosphere, the limiting frequency below which a wave component is reflected by, and above which it penetrates through, an ionospheric layer. (QSTAG 595)*

Decile. *Statistical values at or below which a given part of a set of data must fall. There are nine deciles which are such that 10 percent of the data is less than or equal to D1, 20 percent of the data is less than or equal to D2.*

Dellingar Fade. *Complete fade-out (which may last for minutes or hours) of HF communications because of the formation of a highly absorbing D layer, lower than the regular E and F layers of the ionosphere, on the occasion of a burst of particles from an eruption associated with a sun spot.*

Deviative Absorption. *Absorption that occurs at frequencies near the critical frequency in conjunction with the slowing up of the radio waves upon reflection from the ionosphere.*

Dielectric.

1. *The insulating material between the plates of a capacitor or adjacent conductors in a cable, or between any two parts of an electronic circuit.*
2. *A medium capable of recovering, as electrical energy, all or part of the energy required to establish an electric field (voltage stress).*

Dipole. *An antenna consisting of two elements and fed with radio frequency energy of opposing polarity at adjacent ends of the elements. (ACP 167)*

Direct Wave. *A wave of electromagnetic radiation that follows the path of least possible propagation time between transmitting and receiving antennas.*

Discrimination Gain. *The degree of rejection of unwanted signals and noise due to the nature of the gain pattern of a receive antenna.*

Diurnal Variation. *Daily variation of the ionosphere.*

Dominant Path. *In HF communications, the sky wave propagation mode (for example 1F2, 2E) which supports the strongest signal at the receive antenna.*

Electromagnetic Radiation. *Radiation made up of oscillating electric and magnetic fields propagated with the speed of light. Includes gamma radiation, X-rays, ultraviolet, visible and infra-red radiation, and radar and radio waves. (QSTAG 595)*

Equivalent Junction Frequency. *In sky wave propagation, the frequency at which, for a given propagation mode, the high and low angle refracted waves coincide at the receive antenna.*

Fading. *The variation, with time, of the intensity or relative phase, or both, of any or all frequency components of a received radio signal due to changes in the characteristics of the propagation path with time. (QSTAG 595)*

Frequency Modulation (FM). *The form of angle modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous value of the modulating signal. (QSTAG 595).*

GRAFEX. Presentation format used by the Ionospheric Prediction Service for displaying data relating to point-to-point HF sky wave circuits. *(JSP(AS)540)*

Great Circle. *A circle on the surface of the earth, the plane of which passes through the centre of the earth. (QSTAG 595)*

Ground Wave. *A radio wave that is propagated over the earth and ordinarily is affected by the presence of ground. Note: Ground waves include all components of waves over the earth except ionospheric and tropospheric waves, and are affected somewhat by the change in dielectric constant of the lower atmosphere. (QSTAG 595)*

High Frequency (HF). *Frequencies from 3 MHz to 30 MHz. (QSTAG 595)*

Hop. *The excursion of a radio wave from the earth to the ionosphere and back to the earth. Note: The number of hops indicate the number of reflections from the ionosphere. (QSTAG 595)*

Intermodulation. *The production, in a non-linear transducer element, of frequencies corresponding to the sums and differences of the fundamentals and harmonics of two or more frequencies, which are transmitted through the transducer. (QSTAG 595).*

Intermodulation Product (IP). *Products generated in the input circuits of the receiver, or by non-linear elements in the vicinity of the receiver, and those products radiated by transmitters.*

Ionosphere. *The region of the atmosphere, extending from roughly 50 km to 400 km altitude, in which there is appreciable ionisation. The presence of charged particles in this region profoundly affects the propagation of electromagnetic radiations of long wavelengths (radio and radar waves). (QSTAG 595)*

Isotropic Antenna. *A hypothetical antenna that radiates or receives equally in all directions. Note: Isotropic antennas do not exist physically but represent convenient reference antennas for expression of directional properties of actual antennas. (QSTAG 595)*

Maximum Usable Frequency (MCF). *The upper limit of frequencies that can be used at a specified time for radio transmission between two points and involving propagation by reflection from the regular ionised layers of the ionosphere. Note: MCF is a medium frequency applicable to 50% of the days of a month, as opposed to 90% cited for the lowest useful high frequency (LBF.) and the optimum traffic frequency (FOT). (QSTAG 595)*

Modulation. *The process, or result of the process, of varying certain characteristics of a signal, called a carrier, in accordance with a message signal. (QSTAG 595)*

Noise.

1. *An undesired disturbance within the useful frequency band.*

2. *The summation of unwanted or disturbing energy intro duced into a communication system from man-made and natural sources. (QSTAG 595)*

Non-deviative Absorption. *Absorption which occurs without the slo*wing up of the associated wavefront (see Deviative Absorption).

Optimum Traffic Frequency (FOT). *The highest frequency that is predicted to be available for skywave transmission over a particular path at a particular hour for 90% of the days of the month. (Note: Also known as Optimum Working Frequency (OWF). The international abbr*eviator is FOT, Frequence Optimum de Travail.) (QSTAG 595)

Path Loss. *The decrease in power in transmission from one point to another. Note: It is usually expressed in decibels, and in radio systems is taken as the loss between transmitting and receiving antennas. (QSTAG 595)*

Permittivity. *A measure of the ease with which a given material can carry electric lines of force.*

Polarisation. *In radio radiation, it is usually the result of emission from the antenna; however, polarisation by reflection also occurs.*

Propagation. *The motion of waves through or along a medium. (QSTAG 595)*

Ray. *Geometrical path of the radiation of wave energy, always in a direction normal to the wavefront.*

Radiation Pattern. *The variation of the field intensity of an antenna as a function of direction. (QSTAG 595)*

Radiation Resistance. *The resistance which, if inserted in place of the antenna, would consume the same amount of power radiated by the antenna.*

Radio Frequency (RF). *Those frequencies of the electromagnetic spectrum normally associated with radio wave propagation. (QSTAG 595)*

Refraction. *The bending of a sound, radio, or light wave as it passes obliquely from one medium to another medium in which its speed is different. (QSTAG 595)*

Reliability. *The probability that an item will perform its intended function for a specified interval under stated conditions. (QSTAG 595)*

Selective Fading. *That type of fading in which the components of the received radio signal fluctuate independently. (QSTAG 595)*

Shot Effect. *One type of limitation to extremely high amplification. The signal can become confused with random noise if the signal is at a low level.*

Side band. *The spectral energy, distributed above and below a carrier, resulting from a modulation process. (QSTAG 595)*

Signal to Noise Ratio. *The ratio of the amplitude of the desired signal to the amplitude of noise signals at a given point in time. (QSTAG 595)*

Skip Distance. *The minimum distance between the transmitting station and the point of return to the earth of the transmitted wave reflected from the ionosphere. (QSTAG 595)*

Skip Zone. *A ring-shaped region within the transmission range wherein signals from a transmitter are not received. It is the area between the furthest points reached by the ground wave and the nearest points at which the refracted sky waves come back to earth. (QSTAG 595)*

Sky Wave. *A radio wave that travels upward in space from the antenna. It may or may not be returned to earth from the ionosphere. (QSTAG 595)*

Solar Flare. *Bright eruption of the sun's surface associated with sun spots, causing intense radio and particle emission.*

Sun Spot. *A disturbance of the solar surface which appears as a relatively dark centre, surrounded by a less dark area. The frequency of sun spots shows a marked period of about eleven years. They have intense magnetic fields, and are sometimes associated with magnetic storms on earth.*

Space Wave. *Combination of ground reflected and direct wave.*

Transmission Line. *General name for any conductor used to transmit electric or electromagnetic energy, eg, telephone line, coaxial feeder, waveguide, etc.*

Troposphere. *The layer of the earth's atmosphere, between the surface and the stratosphere, in which 80% of the total mass of air is concentrated and in which temperature normally decreases with altitude. (QSTAG 595)*

Virtual Height. *The apparent height of an ionised layer as deduced from the time interval between the transmitted signal and the resulting ionospheric echo, assuming perfect reflection occurs within the ionosphere.*

Wavelength. *The distance travelled in one period of cycle by a periodic disturbance. It is the distance between corresponding phases of two consecutive waves of a wave train. (ACP 167)*

ABBREVIATIONS

The following abbreviations are used in this publication. Their sources are as shown.

JSP(AS) 101

altn	Alternate
AM	Amplitude Modulated
CW	Continuous Wave
GMT	Greenwich Mean Time
HF	High Frequency
kHz	Kilohertz Per Second
LF	Low Frequency
MF	Medium Frequency
MHz	Megahertz Per Second
pri	Priority
ratt	Radio Teletype
RF	Radio Frequency
SHF	Super High Frequency
SOI	Signal Operation Instructions
SSB	Single Side-band
TAR	Tactical Air Request
UHF	Ultra High Frequency
VHF	Very High Frequency
VLF	Very Low Frequency

Common Military Usage

DEFCOMMARS	Defence Communications Automatic Relay Station
DGJCE	Director General of Joint Communications- Electronics
EHF	Extra High Frequency
Z	Zulu

Universal Usage

ALF	Absorption Limiting Frequency
dB	Decibel
FOT	Optimum Traffic Frequency
IP	Intermodulation Product
IPS	Ionospheric Prediction Service
MCF	Maximum Usable Frequency
OWF	Optimum Working Frequency
PCA	Polar Cap Absorption
RPC	Radio Path Capability
SID	Sudden Ionospheric Disturbance
UT	Universal Time

CHAPTER 1

FUNDAMENTAL CONSIDERATIONS

SECTION 1–1. INTRODUCTION

Radio Waves

101. Radio waves are propagated through space in all directions. When the correct antenna and orientation are selected, the intensity of radiated power can be increased in a desired direction, while decreasing the amount radiated in unwanted directions. The amount of power arriving at the receiving end will depend on the antenna chosen and the characteristics of the path through which the radio wave travels. HF radio waves have two possible modes of propagation, ground wave and sky wave. The modes have different characteristics, although the two modes may occur together.

Frequency Spectrum

102. The frequency spectrum is a limited resource, and is allocated on an international level by the International Radio Consultative Committee (CCIR), and on a national level by the Department of Communications. The Defence coordinator of frequencies is the Director General of Joint Communications-Electronics (DGJCE).

103. The frequency spectrum is divided into various bands which correspond to practical propagation modes. These are shown in Table 1 – 1.

TABLE 1–1. RADIO FREQUENCY BANDS

Serial	*Frequency Band*	*Designation*	*Abbreviation*
(a)	*(b)*	*(c)*	*(d)*
1	15-30 kHz	Very Low Frequency	VLF
2	30-300 kHz	Low Frequency	LF
3	300-3000 kHz	Medium Frequency	MF
4	3-30 MHz	High Frequency	HF
5	30-300 MHz	Very High Frequency	VHF
6	300-3000 MHz	Ultra High Frequency	UHF
7	3000-30 000 MHz	Super High Frequency	SHF
8	30 000-3 000 000 MHz	Extra High Frequency	EHF

SECTION 1–2. FADING

General

104. Fading is a repetitive rise and fall in signal level. Generally, the fading rate increases with frequency because a particular motion in the ionosphere causes a greater phase shift at the shorter wavelengths. Fading is generally, though not exclusively, a consequence of the presence of multiple transmission paths.

105. **Interference Fading.** Interference fading, as its name implies, is caused by interference between two component waves when one or both path lengths are changing, perhaps due to fluctuations in the ionosphere or troposphere, or due to reflections from a moving surface (auroral flutter). The period is relatively short, usually up to a few seconds. Fast interference fading is often called flutter.

106. **Polarisation Fading.** Polarisation fading is brought about by continuous changes in polarisation due to the effect of the earth's magnetic field on the ionosphere. Signals are at a maximum when they arrive with the same polarisation as the receiving antenna. The period of fading is up to a few seconds.

107. **Absorption Fading.** Absorption fading is caused by irregularities in the troposphere or ionosphere. It generally lasts for periods of up to an hour.

108. **Skip Fading.** Skip fading occurs when a receiver is on the edge of a skip zone and the changes in maximum usable frequency (MCF) cause the skip distance to vary, causing the period of fade to be highly irregular.

109. **Selective Fading**. Selective fading is the name given to a form of fading characterised by severe modulation distortion in which the path length in the ionosphere varies with frequency to such an extent that the sideband frequencies are differently affected. It is most severe when ground and sky waves are of comparable intensity.

CHAPTER 2

RADIO NOISE

SECTION 2–1. TYPES AND EFFECTS OF RADIO NOISE

General

201. The most significant factor limiting the effectiveness of communications at any frequency is noise. Noise may emanate from a large number of sources, but with the selection of appropriate frequencies, antennas and other variables, the effects of noise can be minimised. The amount of noise that an antenna receives depends on the antenna gain and directivity. Directional antennas can be used to effectively eliminate noise radiating from directions other than that of the transmitter. This chapter deals with the sources of noise and effective methods of reducing the degradation which noise can cause.

202. **Source of Noise.** Noise is present in all systems. In the HF band, the significant contributors to noise are:

a. atmospheric noise,

b. man-made noise, and

c. receiver and transmitter noise.

Atmospheric Noise

203. Atmospheric radio noise, commonly called static, is noise over which we have no control. It results mainly from the variations in both the weather conditions and the sun's radiation. During a local thunderstorm, the noise level may increase by 10 decibels (dB) over the average noise level.

204. **Minimising Atmospheric Noise.** The many factors which must be considered if the effects of atmospheric noise are to be minimised are as follows:

a. *Frequency.* Ensure that the frequency used is the one which gives indications of containing the least atmospheric noise when compared with the other frequencies available (ie, the frequency is quiet).

b. *Geographical Location.* Locations vary in the intensity of the local atmospheric noise level. Tropical areas are high on the atmospheric noise curve.

c. *Sunspot Activity.* Days of increased sunspot activity (high number) will mean an increase in the density of the ionisation layers.

d. *Time of Day.* Midday will see an increase in the level of noise on some frequencies, while at night, frequencies will be quieter.

Man-made Noise

205. Man-made noise can come from a large variety of sources, and the source must be identified in order to overcome the problem. Some of the possible sources are given in Table 2–1.

TABLE 2–1. NOISE SOURCES

Serial	*Type of Noise*	*Possible Source*
(a)	*(b)*	*(c)*
1	Clicking, regular or irregular	Calculating machines (electric) Cipher machines Flashing signs Mercury-arc rectifiers Relay Switches Telephone dials Teletype writers Typewriters (electric)
2	Popping	Ignition systems Regulators of vehicular charging generators
3	Buzzing	Buzzers Electric razors
4	Humming	Antenna too close to power line Faulty receiver Poor ground connection
5	Heavy rushing	Shot effect Thermal agitation
6	Whining	Electric motors High speed generators Magnetos

Serial	*Type of Noise*	*Possible Source*
(a)	*(b)*	*(c)*
7	Continuous splatter	Arc welders Defective insulation, loose contacts, arc-over in electrical equipment and wiring Low speed generators HF apparatus (diathermy, etc) Loose fuses Neon signs Power lines grounded on tree limbs Various electrical office equipment

206. Experience will be the best guide as to the cause of man-made interference, and to the means of suppression. It may be necessary to incorporate filters, improve shielding or earthing, or remove the source of interference.

Receiver and Transmitter Noise

207. Intermodulation products (IPs) are the result of the overdriving of transmitters or the siting of equipments too close to each other. This will cause the signal to become distorted and lower the quality of the received signal.

208. **Minimising the Effects of Radio Noise.** To minimise the likelihood of IPs, all equipment should be operated within the linear region of the component characteristic curves. This can be ensured by periodically checking the transmitted or received signal for the presence of IPs using a spectrum analyser. IPs should be at least 35 dB below the peak radiated power to ensure that they do not contribute appreciably to system noise. Regular maintenance of equipment will serve to minimise the possibility of excessive IPs. The effects of radio noise can be minimised by:

a. correctly earthing the radio installation,

b. using the most efficient antenna,

c. avoiding obvious noise sources where possible,

d. efficient equipment alignment and maintenance, and

e. choice of frequency.

CHAPTER 3

GROUND WAVE PROPAGATION

SECTION 3–1. GROUND WAVES

Introduction

301. The term ‘ground wave’ is applied to waves that stay close to the ground and do not reach the receiving point by reflection or refraction from the ionosphere. The ground wave comprises:

a. the surface wave, which predominates for HF communications; and

b. the space wave.

The Surface Wave

302. A wave that travels in contact with the earth’s surface is called a surface wave (Figure 3–1). Since the wave front is in contact with the ground, it will lose some energy into the ground. The amount of energy lost depends upon the conductivity of the earth at any given point.

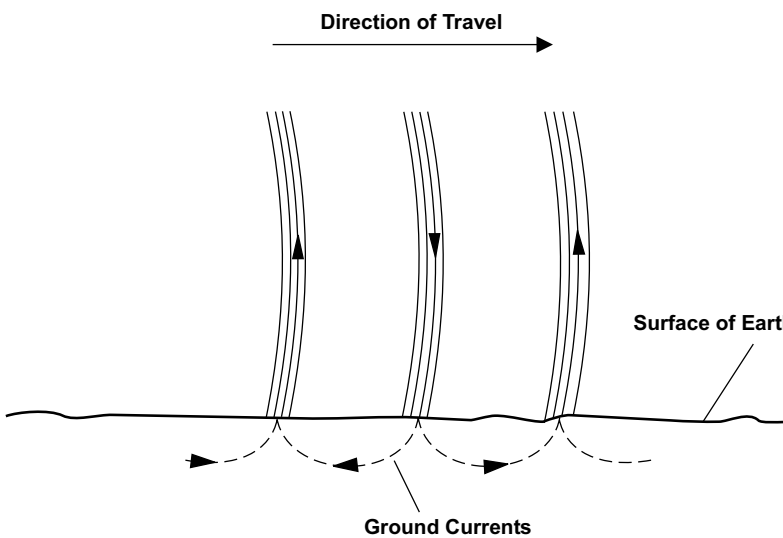


Figure 3–1. Surface Wave

303. If the ground is a good conductor, part of the energy will be returned to the other wave fronts. If it is a poor conductor, much of the energy will be lost into the ground. Table 3–1 compares the different types of surface.

TABLE 3–1. CONDUCTIVITY COMPARISON TABLE

Serial	*Type of Surface*	*Relative Conductivity*
(a)	*(b)*	*(c)*
1	Sea water	Good
2	Large bodies of fresh water	Fair
3	Wet soil	Fair
4	Flat, loamy soil	Fair
5	Dry, rocky terrain	Poor
6	City areas	Poor
7	Desert	Poor
8	Jungle	Poor

The Tilting Effect

304. 304. Since some of the energy is lost into the ground, the wave is retarded at the ground. This retarding effect becomes less noticeable with increasing height above the ground. This effect causes the whole wave front to tilt forward (Figure 3–2). Poor conducting surfaces cause high loss and greater tilt and, finally, total absorption of energy. The angle of the tilt also varies with frequency. As frequency increases, the angle of tilt increases.

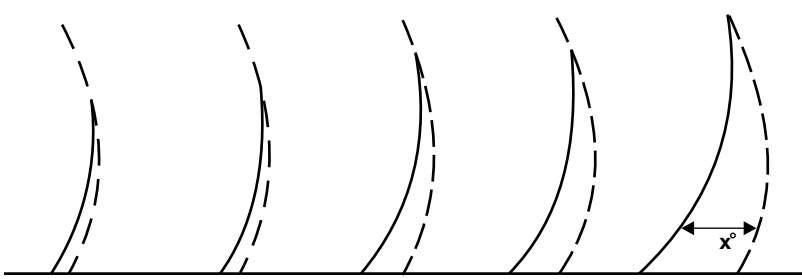


Figure 3–2. Tilting Effect

The Space Wave

305. The conditions that exist when the transmitting and receiving antennas are within line of sight of each other are shown in Figure 3–3. One ray travels directly from the transmitter to the receiver and, consequently, is attenuated in about the same way as a wave in free space. However, the wave from the transmitting antenna also strikes the ground between the two antennas, and the ray that does so at the proper angle to reach the receiving antenna combines with the direct ray to produce the actual signal at the receiving antenna.

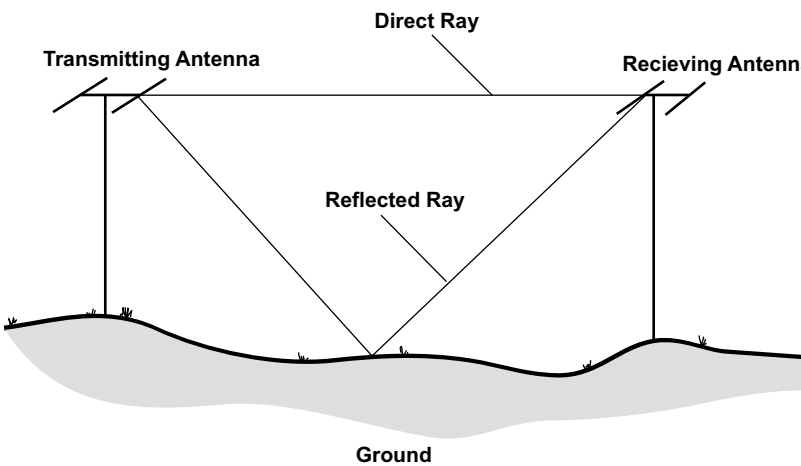
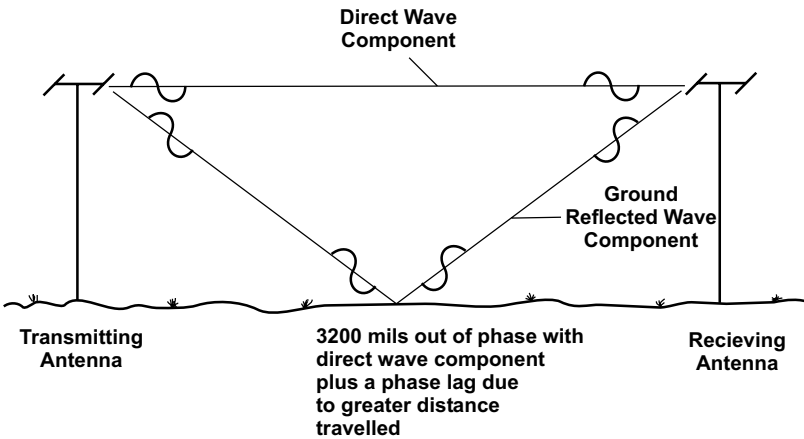


Figure 3–3. Direct and Reflected Rays

306. At its point of reflection, the reflected wave suffers a change of phase which, for small angles of incidence, is very nearly 3200 mils. Thus, when both transmit and receive antennas are close to the ground, the two components of the space wave practically cancel the wave out (Figure 3–4).



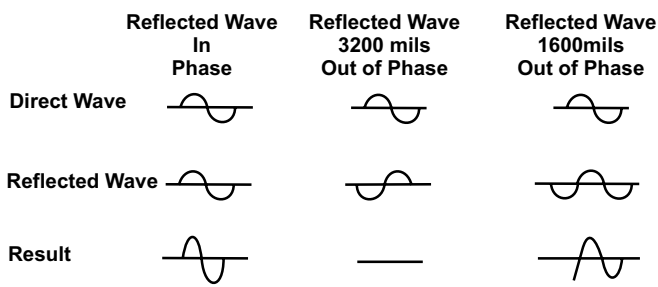


Figure 3–4. Comparison of Wave Fronts of Direct and Reflected Waves

307. As the antenna height is increased, the path of the reflected ray becomes greater than that of the direct ray. In this case, a further phase change is introduced. The two components no longer cancel as they are no longer equal and opposite. As the antenna height is further increased, the space components become increasingly important, and the resultant field must be calculated as a combination of both the space and surface waves.

308. For small elevation, the change in field strength is small. In some cases, the relative phases of the surface and space wave results in a decrease at first, but eventually, the signal increases steadily with height.

SECTION 3–2. PLANNING AND PROPAGATION OF GROUND WAVES

Ground Wave Planning

309. As previously noted, the term ‘ground waves’ includes surface waves, direct waves and ground reflected waves. The proportion of surface wave energy to direct wave energy depends on the antenna. The minimum effective antenna height is that height at which the antenna radiates 50 per cent surface wave and 50 per cent direct wave. If the direct wave component is desired, the antenna should be elevated above the minimum effective antenna height, and if the surface wave component is desired, the antenna should be as close to the ground as possible (and must be vertically polarised). In tactical communications, a small antenna is usually located close to the ground, so the surface wave will predominate. To obtain propagation in which the direct wave is dominant, it is necessary to have a very high antenna, which at HF is usually impractical. Strategic communications do not normally rely on ground wave propagation.

310. **Ground Wave Planning Considerations.** Factors which should be considered when planning ground wave paths include:

a. transmitting power,

b. transmitter antenna gain,

c. receive antenna discrimination gain,

d. type of ground,

e. antenna elevation,

f. atmospheric noise,

g. type of modulation,

h. reliability desired, and

i. distance.

Surface Wave Propagation

311. Surface wave propagation is propagation of radio frequency (RF) energy along the curved surface of the earth. It is the propagation mode responsible for almost all daytime reception of signals in the standard broadcast band and is commonly used for moderate range communications in the 2 to 3 megahertz per second (MHz) region, especially over salt water. Surface wave propagation depends upon the finite conductivity of the earth, and the received field intensity depends on the type of terrain over which the transmission passes, the frequency, transmitter power, type of transmitting and receiving antennas, antenna heights, and noise intensity. Poor ground is characterised by steep hills or sandy soil. Examples of poor terrain which attenuate surface waves at HF, are steep hills, sandy soil, fertile farming regions, frozen arctic or antarctic regions and dense jungle foliage.

Surface Wave Planning

312. Factors which should be considered wheln planning surface wave paths include:

a. short length of path (range);

b. transmitter power; and

c. antenna type.

CHAPTER 4

THE IONOSPHERE

SECTION 4–1. THE IONOSPHERE

General

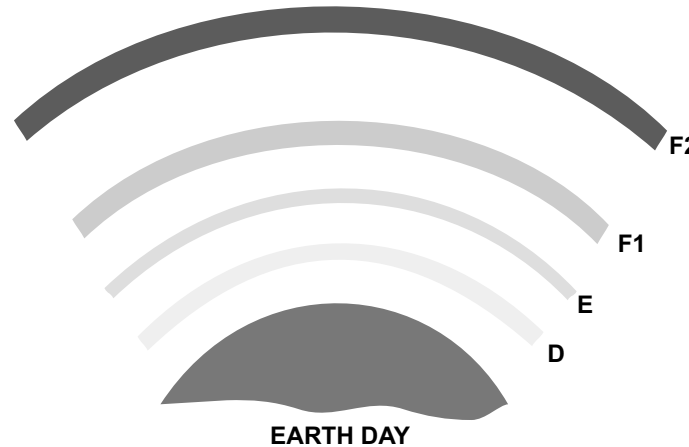
401. The ionospheric or sky wave is important at frequencies above 500 kilohertz (kHz) and below 30 MHz in providing long distance communications. The nature of the ionosphere causes reflection of the skywave.

The Ionosphere

402. The degree of ionisation in the ionosphere is strongly influenced by variation in the radiation from the sun and, therefore, changes with the time of day, the season of the year, the latitude and, to some extent, the longitude. For all practical purposes, four layers in the ionosphere have been identified, which are, from the lowest to the highest, D, E, Fl and F2. The D, E and F1 layers have average daytime heights of 70 km, 120 km and 200 km, respectively, above the surface of the earth. The F2 layer height, however, ranges from about 230 km in winter to 320 km in summer. At night, the Fl layer merges with the F2 layer to form the F layer at an average height of about 250 km. The D layer is a weak refracting agency which disappears at night. The E layer intensity is so weak at night that it is useless for radio transmission. Figure 4–1 illustrates a typical cross section of the ionosphere under average day and night conditions.

403. **D Layer.** The D layer is a region of low ionisation which does not have the well defined maximum associated with other layers. It occurs only during daylight hours and extends diffusely from about 50 km to about 100 km above the earth's surface. In this region, the density of electrons is not sufficient to cause appreciable refraction, although radio waves may suffer appreciable attenuation when passing through it.

404. **E Layer.** The E layer occurs during daylight hours and has its maximum density at heights between 100 km and 150 km. It remains very weakly ionised throughout the night. During daylight hours, its height remains practically constant, and day-to-day variations are not large. The electron density is lower in winter than summer since the position of the sun reduces the ionising effect.



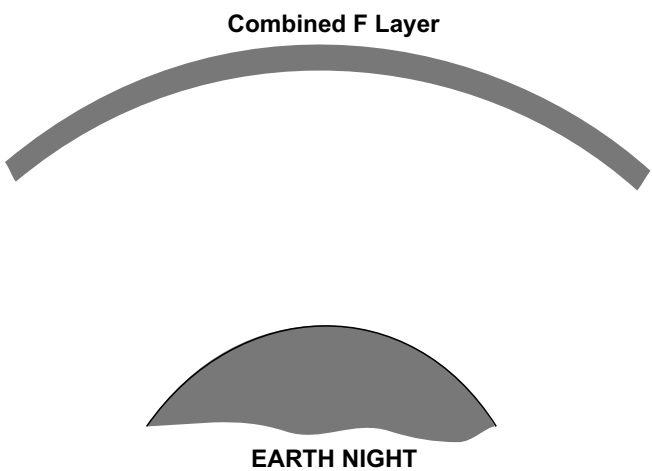


Figure 4-1. Average Layer Distribtion of Ionosphere

405. **F, F1 and F2 Layers.** The region of the ionosphere lying between about 150 km and 500 km above the earth's surface is known as the F region. A single F layer occupies this region at night, but in daytime it divides into two layers. The lower is known as Fl, and the upper as F2. The F1 layer at around 200 km shows no great variations in height, and its density is lower in winter than in summer. The F2 layer, which is the uppermost and most ionised of all the layers, shows considerably greater variations than the others. Its daytime height is very dependent on solar heating of the upper atmosphere, and varies between 150 km and 300 km in winter, and between 306 km and 500 km during summer. The night-time layer is, likewise, dependent on atmospheric temperature, and is extremely variable in height and density.

SECTION 4–2. IONOSPHERIC CHARACTERISTICS, SKY WAVE PROPAGATION

Critical Frequency

406. In addition to height, the principal ionospheric characteristic which controls or determines long-distance radio transmission is the ionisation density of each of the layers. The higher the frequency, the greater the density of ionisation required to reflect waves back to earth. In other words, the shorter the length of the waves, the denser or more closely compacted must be the medium to refract them. Therefore, the upper layers, which are the most highly ionised, reflect the higher frequencies, whereas the D layer, which is the least ionised, does not reflect frequencies above approximately 500 kHz. Therefore, for each layer, there is a value of highest frequency, called the critical frequency, at which waves sent vertically upward are reflected directly back to earth. Waves of frequencies higher than the critical frequency pass through the ionised layer and are not reflected back to earth, unless they are reflected from an upper layer. Waves of frequencies lower than the critical frequency are reflected back to earth, unless they are absorbed by, or have been reflected from, a lower layer.

407. This phenomenon may be understood in terms of the combined refractive and reflective effects of ionisation on an electromagnetic wave. When a ray, or train of waves, enters an ionospheric layer, it is retarded as soon as it starts to penetrate the layer. This process of refraction is similar to the refraction of light passing from air to water. When the signal enters the ionosphere at a 3200 mil angle, there is no refraction of the wave, ie, the whole wave front is retarded uniformly. The higher the frequency of the signal, the deeper it must penetrate the layer before it surrenders all of its energy. The surrendered energy is reradiated by the layer, directly down to the area from which the transmission originated.

Critical Angle

408. At angles of incidence near the vertical, a given frequency passes through the ionosphere. As the angle lessens, a point is reached at which the wave is reflected back to earth. This angle is called the critical angle. The minimum distance between the transmitting station and the point of return to the Earth of the transmitting wave, is called the skip distance. As the angle of incidence decreases, the skip distance increases. The skip zone is the distance from where the ground wave of a set frequency finishes to where the skip distance finishes (Figure 4–2).

Virtual Height

409. The curved path shown in Figure 4–3 describes the actual path of the signal as it passes through the ionospheric layer which reflects it. The time of transmission of the radio wave along the actual path B/C/D in the ionised layer is considered to be the same as would be required for transmission along path B/A/D if there were no ionised particles present, and a perfect reflecting surface at A instead. The height, H, from the earth to the intersection of the two projected straight parts of the path is called the virtual height of the layer. Note that this virtual height is considerably greater than the actual layer height. However, it is a convenient and important quantity in measurements and applications involving ionospheric reflections.

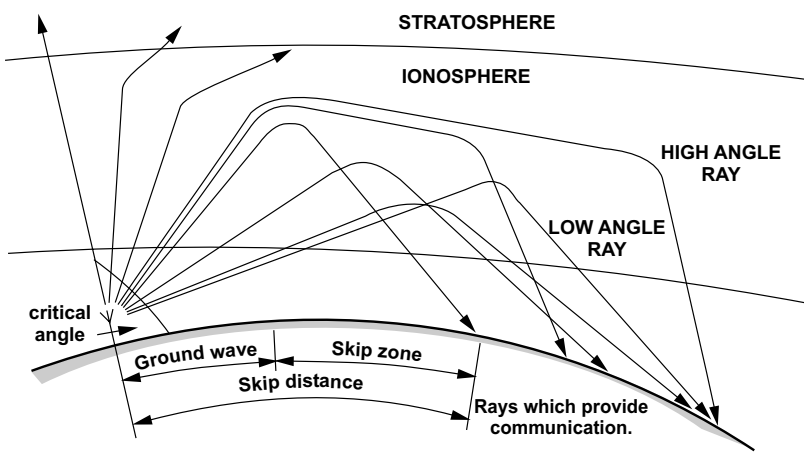


Figure 4–2. Sky Wave Propagation

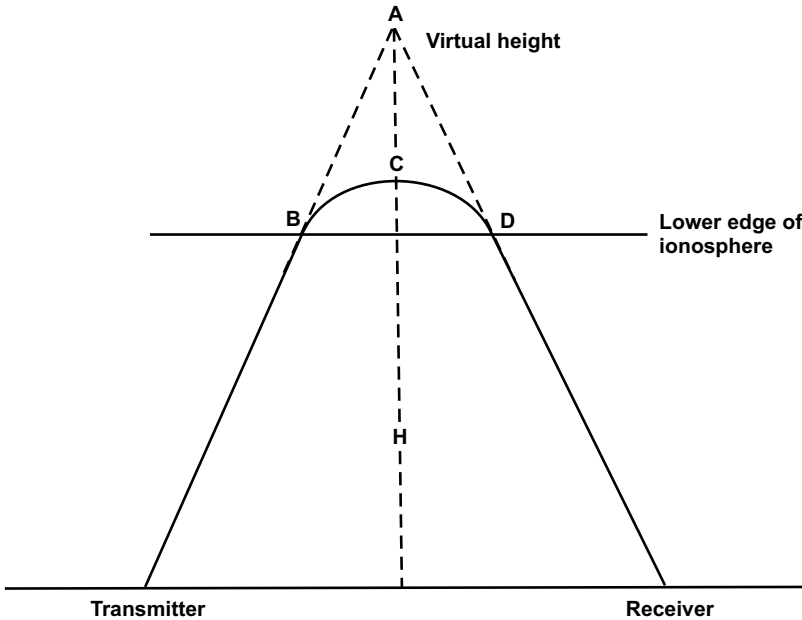


Figure 4–3. Virtual Height

SECTION 4–3. REGULAR IONOSPHERIC VARIATIONS

General

410. Since the existence of the ionosphere is dependent on radiation primarily from the sun, it follows that the movements of the earth about the sun, or changes in the sun's state of activity, will result in variations in the structure of the ionosphere. These variations include those which are normally regular and which, therefore, can be predicted in advance, and the irregular variations resulting from the abnormal behaviour of the sun. The four classes of regular variations are:

a. the diurnal, or daily;

b. the seasonal;

c. the 11-year; and

d. the 27-day.

Diurnal Variation

411. To compensate for the resulting variations in the ionosphere, it is suggested that higher MUF be used during the daytime, and lower MUF at night. The reason for this is that the ion density of the F2 layer is greater during the daytime, and will reflect radio waves of higher frequency than the F layer w ill reflect during the night. The higher frequency waves suffer less absorption in passing through the D layer, whereas at night, the disappearance of the D layer permits the use of lower frequencies. Figure 4–4 illustrates the diurnal variation of the important ionospheric layers.

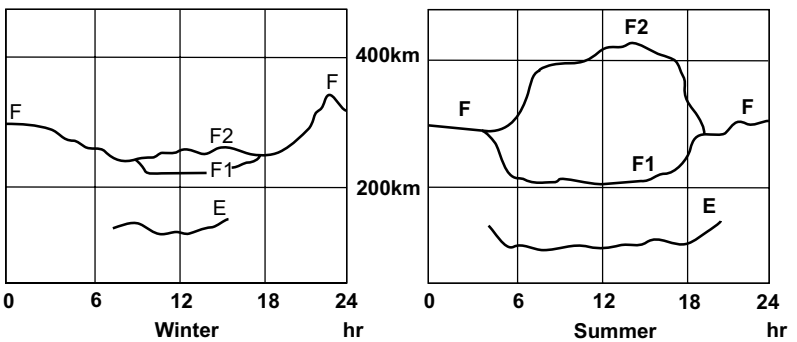


Figure 4–4. Typical Diurnal Variation of Ionospheric Layers

Seasonal Variation

412. As the apparent position of the sun moves from one hemisphere to the other with corresponding changes in seasons, the maximum ion density in the D, E and FI layers shifts accordingly, each being relatively greater during summer. The F2 layer, however, does not follow this pattern in seasonal shift. In most locations, the F2 ion density is greater in winter than in summer, which is the reverse of what might be expected from simple theory. In winter, the ion density of the F2 layer rises to a sharp peak at about noon, and assumes a much higher density than in summer.

Eleven-year Cycle

413. The method of evaluating the 11-year cycle of sunspot numbers is by the use of the Wolf sunspot number, a number obtained for each day by multiplying by 10 the number of distinct, visible sunspot groups and adding

this to the number of individual spots observable in the groups. For months at a time, the visible surface of the sun may be devoid of spots and so the Wolf sunspot number is zero. At other times, even the mean sunspot number has been known to rise as high as 140, with daily values running into the hundreds. These conditions occur at the maximum of the sunspot cycle. Although the time from minimum has been found to be variable, it averages around 11 years. Also, the height of the maximum and the depth of the minimum vary from cycle to cycle. Increased sunspot activity is reflected in an increase in ion density of all the ionosphere layers, resulting in higher critical frequencies for the E, Fl and F2 layers, and higher absorption in the D layer. This permits the use of higher frequencies for communications over long distances at times of sunspot maxima than would be usable at times of sunspot minima. The increased absorption in the D layer, which has the greatest effect on the lower frequencies, requires that higher frequencies be used, but the overall effect is an improvement in propagation conditions during sunspot maxima, as the critical frequencies are raised more than the absorption limits.

Twenty-seven-day Variation

414. Another cycle due to sunspot activity is the 27-day variation resulting from the rotation of the sun on its axis. As the number of sunspots changes from day to day with solar rotation or the formation of new spots or the disappearance of old ones on the visible part of the sun, absorption by the D layer also changes. Similar changes are also observed in the E layer critical frequency. These variations are experienced widely and they are effects that may be observed at one station but not at others. Although fluctuations in F2 layer critical frequencies from day to day are greater than for any other layer, these fluctuations are not of a world-wide nature. Because of this variability of the F2 layer, precise predictions of its critical frequencies cannot be made for individual days, although trends can be predicted. In selecting frequencies for long distance communications, it is necessary to allow for these fluctuations.

SECTION 4–4. IRREGULAR IONOSPHERIC VARIATIONS

General

415. In addition to the more or less regular variations in the characteristics of the ionosphere, a number of singular, transient effects, though unpredictable, have an important bearing on propagation phenomena. Some of the more prevalent of these effects are in Annex A to this chapter. They are:

a. sporadic E layer;

b. sudden ionospheric disturbance (SID) (Dellingar Fade); and

c. ionospheric storms.

Sporadic E Layer

416. The sporadic E layer, also known as the Es Layer, is an ionised cloud that appears at indefinite intervals, and at a slightly greater height than the normal E layer. Sometimes, the sporadic E consists of an extremely efficient radiating surface that is capable of reflecting so much of the energy radiated from the transmitting antenna, even at frequencies of 10 to 15 MHz, that reflections from the other layers of the ionosphere are blanked out completely. At other times, the sporadic E cloud may be so thin that, although its presence can be verified by sounding, reflections from the upper layers can be easily received through it. The sporadic E layer may occur during the day or night. Its occurrence is frequent, and thus, from 25 to 50 per cent of the time, long-distance propagation at frequencies up to 15 MHz is rendered possible by this means in middle latitudes. Occurrence of sporadic E is not usually simultaneous at all stations. In general, tropical stations exhibit less sporadic E than stations in higher latitudes.

SID (Dellingar Fade)

417. A notable irregularity of the ionosphere and of radio wave transmission is the sudden type of disturbance manifested by a radio fade-out. SID comes without warning and may prevail from a few minutes to several hours. All stations lying on the sunward side of the earth are affected and, at the onset of SID, receiving station operators are inclined to believe that their radio sets have suddenly gone dead. The appearance of SID is coincidental with the onset of a bright solar eruption, and its duration is the same as that of the eruption. Such an eruption causes a sudden abnormal increase in the ionisation of the D layer, frequently with simultaneous disturbances in terrestrial magnetism and earth currents. Such increases in D layer ionisation usually result in total absorption, in this region, of all frequencies above 1 MHz.

Ionospheric Storms

418. An ionospheric storm is a period of disturbance in the ionosphere, during which there are large variations from normal, of critical frequencies, layer heights, and absorption. These storms may last for periods of varying intensity (from several hours to several days), and usually extend over the entire earth. HF sky wave transmission above approximately 1500 kHz then

shows low intensity and is subject to flutter (interference) fading. During the first few hours of severe ionospheric storms, the ionosphere is turbulent, stratification is destroyed, and radiowave propagation is erratic. During the latter stages of severe storms and during the whole period of more moderate storms, the upper part of the ionosphere is expanded and diffused. The critical frequencies are much lower than normal because of a decrease in ion density, and the virtual heights of the layers are much greater, so that MUFs are much lower than normal. It is often necessary to lower the working frequencies to maintain communications during one of these storms. There is also increased absorption of radio waves during the storm. Ionospheric storms are most severe at the higher latitudes and decrease in intensity toward the equator. These storms are caused by abnormal particle radiation from the sun, and are likely to occur during periods of great solar activity. The storms are most likely to start about two days after an active sunspot group crosses the centre of the sun's disc.

Absorption Limiting Frequency (ALF)

419. The presence of ions in the upper atmosphere not only causes refraction and the return to earth of a radio wave of sufficiently low frequency but also causes part of the wave energy to be absorbed. The collision of electrons with neighbouring molecules of air reduces the intensity of the radio wave below that resulting from the normal spreading of the wave front as it travels out from the transmitter. This absorption process is also of great importance in the practical use of ionospheric radio transmission. During the day, absorption takes place mainly in the D layer of the ionosphere. Electron densities in this region are considerably less than in the higher regions, but the increased density of the atmosphere itself results in an increase in the number of collisions between electrons and molecules of air, and more than compensates for the scarcity of electrons. During the night, ionisation and absorption in the D layer becomes negligible. However, there is some absorption for frequencies near the MUF of the F2 layer because waves at such frequencies are retarded to such an extent that there is sufficient time for appreciable energy loss to take place in spite of the relatively small number of collisions. Such absorption is called deviative absorption, because it occurs in conjunction with retardation, which causes refraction of the waves. Absorption which takes place, even though the wave is not appreciably retarded, is called nondeviative absorption. The absorption in the D layer is largely nondeviative.

420. At certain frequencies of transmission, radio waves penetrating into the ionosphere, primarily in the D layer and in the lower portion of the E layer, lose some of their energy by absorption. Generally speaking, the higher the frequency used, up to the limit of the MUF, the less will be the total

absorption and the more satisfactory will be the level of communication. Absorption is at a maximum for frequencies of about 500 kHz to 2 MHz in the daytime, and decreases for both higher and lower frequencies at night. Thus, for frequencies above about 1 MHz, the strength of the received sky waves will, in the daytime, increase with frequency (corresponding to decreasing absorption). Finally, a frequency will be reached for any given sky wave path where the strength of the received signal overcomes the noise level. This frequency is called the Absorption Limiting Frequency (ALF). Frequencies lower than the ALF are absorbed to such an extent as to render them too weak for useful communication. It should be noted, however, that the ALF depends on the power of the transmitter as well as on the distance concerned. At night, the noise level increases with decreasing frequency so that, as the frequency is lowered, the signals become weaker with respect to the noise and the ALF is eventually reached. Thus, the term ALF may apply to either day or night transmission, and to power output of the transmitter.

Optimum Working Frequency (OWIF) (Optimum Traffic Frequency (FOT))

421. The density of the ionospheric layers may vary, hour by hour and from day to day. However, the MUF is based on the average of long range predictions, which ignores short term variations. This is why the OWF (FOT) is based at 85 per cent of the MUF of a particular transmission path. As the ALF is nearly equal to the MUF, the OWF (FOT) must be selected at a value consistent with both these factors. Moderate ionospheric storms may require radio operation at lower frequencies during this period, as the critical frequencies are usually lower.

Annex: A. Irregular Variations of Ionosphere

TABLE 4–1. IRREGULAR VARIATIONS OF IONOSPHERE

Serial	*Type of Variation*	*Effect on Ionosphere*	*Effect on Communications*	*Method of Compensation*
(a)	*(b)*	*(c)*	*(d)*	*(e)*
1	Sporadic E Layer	Clouds of abnormal ionisation occuring in the E layer or slightly above for a large portion of time each month result in abnormally high critical frequencies. Usually spotty in geographic extent and time.	Excellent transmission within normal skip distance. Occasionally, long-distance communications on frequencies of 60 MHz or higher are possible.	Frequency may have to be lowered to maintain short skip communications. At times long-distance communications on abnormally high frequencies are possible.
2	SID	Unusual amount of ultra-violet radiation from solar flare results in abnormally high ionisation in all layers. Ionisation increase occurs with great suddenness throughout daylight portion of earth.	Normal frequencies above 1 or 1.5 MHz are rendered useless because of high absorption in the abnormally ionised D layer. Frequencies considerably higher than normal will survive this absorption for short hops. Low frequencies may not penetrate the D layer and thus may be transmitted for long distances.	Raise working frequency above normal for short-hop transmission. Lower frequency below normal for long-hop transmission.

Serial	*Type of Variation*	*Effect on Ionosphere*	*Effect on Communications*	*Method of Compensation*
(a)	*(b)*	*(c)*	*(d)*	*(e)*
3	Ionospheric Storm	An ionospheric storm usually accompanies magnetic disturbance occurring about 18 hours after SIDs. Probably both are due to abnormal particle radiation. The upper ionospheric expands and diffuses, critical frequencies are below normal, virtual heights are above normal. Severest effects are toward geomagnetic poles, decreasing toward the equator. Duration is a few minutes to several hours; effects disappear gradually in a few days.	Limits number of usable high frequencies.	Use frequencies lower than normal, particularly in high latitude circuits.

CHAPTER 5

PREDICTION PUBLICATIONS AND CHARTS

SECTION 5–1. INTRODUCTION

501. By the use of a number of techniques, it is possible to predict several months in advance the various important characteristics of the ionosphere above any point on the surface of the earth. Such predictions are useful in the selection of optimum frequencies for radio communication over a definite path at particular times. The average variations of the critical frequency and MUF factors are sufficiently well known to permit long-range predictions to be made for average conditions on ionospherically quiet days (days without ionospheric disturbances). One of the basic principles employed in all ionospheric predictions is the relation of ionospheric characteristics to the sunspot cycle. The actual prediction consists of first predicting the solar activity and then deducing the corresponding trends of seasonal, diurnal, and geographic variations of the ionospheric characteristics.

502. The source of ionospheric predictions relating to Australia is the Ionospheric Predicttion Service (IPS), operating under the auspices of the Australian Government. This chapter deals with publications and charts of the IPS which are frequently used by the Army. For predictions outside the Australian region, the IPS could be consulted on the means of obtaining predictions.

503. Universal time (UT) is used for all the predictions. This is the zero meridian time, also known as Greenwich Mean Time (GMT) or Zulu (Z) time. In some forms of presentation, the prediction is repeated as the 24 UT prediction.

504. The term ‘District’ is sometimes used, usually for a circuit prediction (eg, Melbourne District). This means that the predictions apply to communication between the named base (eg, Melbourne) and any point within about 300 km, or between any two points within about 250 km of the base, provided the distance between the two points is not more than about 400 km.

505. The unit of frequency used in IPS charts and predictions is MHz. In some formats, kHz are used, but this will be indicated when applicable.

506. In all IPS publications, angles are given to the nearest whole degree, or degrees and decimal fractions of a degree, not degrees and minutes.

SECTION 5–2. FREQUENCY PREDICTIONS

General

507. The basic prediction service is the provision of regular monthly frequency-type predictions in various forms. These predictions are for specific calendar months and normal propagation conditions. During ionospheric disturbances, conditions may be quite different from those predicted. The predictions are computed about ten weeks in advance of the month to which they apply and should be received by the user about six weeks before that month. In addition to the monthly prediction service, frequency-type predictions, in various forms, can be provided for:

a. months other than the regular month;

b. several months;

c. a four-week period centred on any nominated day; and

d. planning predictions for four seasonal months (March, June, September and December) and for two or three standard solar indices (0 and 100, or 0, 100 and 150).

508. The initial step in providing predictions in any form involves the production of one or more point-to-point circuit predictions. A frequency-type, point-to-point circuit prediction includes the 24-hourly values of the median FMUF (MUF of the F2 layer) and the upper and lower decile MUFs for the median EMUF (MUF of the E layer) (if E layer propagation is possible) and the ALF for the first two modes, except for circuits under 500 kin long and over 12 000 kin long. In the case of the shorter circuits, predictions are produced for only the first mode. For long circuits, the most probable mode is one with hop length about 3000 kin long, so predictions are made for one mode having 3000 kin hops. This information, printed in GRAFEX format, is sufficient for many applications. GRAFEX predictions are discussed in paragraph 510.

509. The usual reason for making frequency-type predictions is to assist in developing a frequency usage plan. If a set of working frequencies is specified, it is possible to process the circuit predictions to produce a frequency usage plan, for example, to nominate the ‘best’ frequency from the set to use each hour, using some selection rules.

GRAFEX Predictions

510. The name GRAFEX is given to a form of presentation of point-to-point circuit predictions. GRAFEX predictions are printed by a computer line printer, giving the predictions in a pictorial form and listing the most important parameters in numerical tabulations. An example of the GRAFEX form is given in Table 5–1.

511. The first line printed gives the circuit name, the path length and the date. The second line gives vertical angles for the various modes. Ranges of possible angles are given for the F modes since the height of the layer varies throughout the day and night. Only one angle is given for each E mode because the height changes for the E layer are small. These angles are valid for frequencies which are not close to the MUF or ALF.

512. The right-hand side of the print-out gives a summary of the MUF (both EMUF and FMUF) and the ALF for each hour over a 24-hour period. If more than one mode is possible, the MUF and ALF for each mode will be included.

513. The left-hand side of the print-out details the propagation characteristics for the range of frequencies at each hour over a 24-hour period. There are eleven propagation categories as follows:

a. ( ) The frequency is above all the normal MUFs. The signal may still be propagated by an unusual mode (eg, sporadic E) or abnormally high ionisation density. This symbol is also used when the frequency is below the lowest ALF.

b. (.) The frequency is below the first F mode upper decile MUF but above the medium MUR The frequency will be propagated on more than three days of the month but less than half the days.

c. (%) The frequency is below the first F mode median MUF but above the lower decile MUR The frequency will be propagated on more than half the days in the month but less than 90% of the days.

d. (F) The frequency is below the first F mode lower decile MUF but above other MUFs. Communication on frequencies in this category should be usable on almost all days except, possibly, when an ionospheric storm is in progress.

e. (E) The frequency is below the first E mode median MUF but above the first F mode median MUR (The variation throughout the month about the E median MUF is very small, so deciles are

not quoted for this layer). Propagation may still be possible by the F layer on a few days of the month.

f. (P) The frequency is below the first E mode MUF and below the first F mode median MUF but above the F mode lower decile MUF Propagation by the first E mode is possible on all days of the month and by the first F mode on more than half the days.

g. (D) The frequency is below the first E mode MUF and below the first F mode lower decile MUF. Propagation is possible by both E and F modes on most days of the month.

h. (M) The frequency is below the first F mode lower decile, below the second F mode median MUF and may also be below the first E MUF The mode by which the signal will be propagated in practice will depend on several factors, including the antenna elevation angle and beam-width used.

i. (S) The frequency is below the second F mode median MUF and below the first mode ALF.

j. (A) Thefrequency is very close to an ALF. (If the ALF is the first mode ALF, the mixed mode symbol (M) overrides this.)

k. (X) The frequency is below the second E mode MUR Other modes such as mixed E and F and higher order F modes are also probable. (Categories b to g must be above the first mode ALF and h, i and k must be above the second mode ALF.)

514. It should be noted that the second F mode upper and lower decile MUFs are ignored. The categories h and i use the median MUF. It is considered that including the extra categories using the second mode deciles would unduly complicate the resulting picture without much advantage. However, there is one very special case when the second mode deciles are used. This is when no first mode F layer communication is possible. This can occur on circuits with hops between 3000 and 4000 km length. If the F layer height is low, the maximum length of the hop may be less than that required. In this case, the highest frequencies that can be used are controlled by the second mode (categories b and c are determined from the second mode deciles; categories d to h are not possible).

Using GRAFEX Predictions

515. Use of a frequency during the hours when the GRAFEX symbol is F should ensure that good communication is achieved most days of the month except when an ionospheric disturbance occurs. Using a frequency when the

TABLE 5-1. GRAFEX PREDICTION FORMAT

NAME	SYDNEY-ALBURY		LENGTH 439 km			DATE A pril 1984					
	VERT. ANG IN DEGREES[1]				IF 50-55		IE 21				
FREQ	00	06	12	18	24	UT		FMU F	EMU F	ALF
MHz										
20.0					F	00		14.6	7.4	3.7
19.5					I	01		14.9	7.7	3.9
19.0					R	02		14.8	7.9	3.9
18.5					S	03		14.8	7.8	3.9
18.0					T	04		14.6	7.6	3.8
17.5						05		14.6	7.1	3.6
17.0					M	06		14.4	6.3	3.2
16.5					O	07		13.6	5.0	2.5
16.0	....	...		.	D	08		12.5	3.2	0.0
15.5	....	...		..	E	09		11.0		0.0
15.0	....	...		..		10		10.0		0.0
14.5	%%%%	%%..	.	.%		11		9.2		0.0
14.0	%%%%	%%%.	.	%%		12		8.6		0.0
13.5	%%%%	%%%	%..	.%%		13		8.3		0.0
13.0	%%%%	%%%	%	.%%	O	14		7.8		0.0
12.5	FFFF	FF%	%..	.%F	N	15		7.7		0.0
12.0	FFFF	FFF	%%.	%FF	E	16		7.7		0.0
11.5	FFFF	FFF	F%..	%FF		17		7.5		0.0
11.0	FFFF	FFF	F%..	%FF	H	18		7.1		0.0
10.5	FFFF	FFF	FF%.	.FFF	O	19		6.6		0.0
10.0	FFFF	FFF	FF%.	...	.FFF	P	20		6.3	3.0	0.0
9.5	FFFF	FFF	FF%	%...	...	%FF F		21		9.6	4.8	2.4
9.0	FFFF	FFF	FFF	%%	...	.	%FF F		22		12.3	6.1	3.1
8.5	FFFF	FFF	FFF	F%%	...	..	%FF F		23		14.1	6.9	3.5
8.0	FFFF	FFF	FFF	F%%	%..	...	F FFF		24		14.6	7.4	3.7
7.5	FBBB	BFF	FFF	FF%	%%%	%..	.F	FFF					
7.0	BBBB	BBF	FFF	FFF	%%%	%%%	..F	FFB					
6.5	BBBB	BBF	FFF	FFF	F%%	%%%	%.F	FBB					
6.0	BBBB	BBB	FFF	FFF	FFF	FF%	%%F	BBB					
5.5	BBBB	BBB	FFF	FFF	FFF	FFF	%%F	BBB					
5.0	BBBB	BBB	BFF	FFF	FFF	FFF	FFF	BBB					
4.5	BBBB	BBB	BFF	FFF	FFF	FFF	FFB	BBB					
4.0	AAAA	AAB	BBF	FFF	FFF	FFF	FFB	BAA					
3.5			BFF	FFF	FFF	FFF	FFB	AA					
3.0			ABF	FFF	FFF	FFF	FBB						
2.5			ABF	FFF	FFF	FFF	FBA						
2.0			BF	FFF	FFF	FFF	FB						
1.5			BF	FFF	FFF	FFF	FB						
1.0			BF	FFF	FFF	FFF	FB						
	00	06	12	18	24						

. USABLE LESS THAN 50% OF DAYS
% USABLE LESS THAN 90% OF DAYS
F FIRST F LAYER MODE ONLY
E E LAYER PROPAGATION POSSIBLE
A HIGH ABSORPTION
P PROPN E (90%) OR F (50-90%) DAYS

M MIXED FIRST AND SECOND F MODES
S SECOND F MODE BUT NO FIRST MODE
A HIGH ABSORPTION
X COMPLEX MODES

symbol is % should be satisfactory on more than half of the days of the month. In this case, the operator should have a backup lower frequency available for those periods when the selected frequency is not usable. A situation requiring the use of a frequency in the % region can arise around local night-time when the MUF is failing rapidly and especially just after dawn when the frequencies are rising sharply. It is not considered desirable to try to use frequencies when the symbol is . except for special purposes.

516. It should be possible to maintain good communication during times when two modes are possible (ie, M and B), provided that the signals by the two modes are not comparable in strength. Generally, signals by the first E mode (ie, B) and the second F mode (ie, M) are several dll weaker than the signal by the first F mode. If the antenna favours the first F mode (by its gain pattern), this will further reduce the possibility of interference. In some cases, the antenna may favour the second F mode, particularly on the lower frequencies. The vertical angle information printed below the circuit name and date may be helpful in determining the successful mode.

517. Operation with frequencies at times when they are in the X region is not desirable as there are likely to be several modes available, at least one of which will interfere with the wanted mode.

518. It is not desirable to operate close to the ALF. The symbol A indicates that the frequency is much too close to the ALF. However, even when the frequency is outside the A region, it may still be unsatisfactory. It is known that the absorption varies from day to day. Also, there is often a small amount of sporadic E layer present which may increase the E layer cut-off frequency. These factors are not currently allowed for in IPS predictions.

519. It is possible to obtain a condensed GRAFEX for specific frequencies only; however, a more convenient form is that shown in Table 5–2, which gives the highest and lowest usable frequencies and two recommended frequencies from a specified set (URRL form). It is also possible to get a similar print-out, but with only one recommended frequency; however, this is of limited application.

520. **Monthly Predictions.** The regular monthly GRAFEX predictions are made available to the users in two ways. These are the production and issue of booklets containing selected circuit predictions and predictions printed by the computer. The reason for producing the booklets is to provide representative sets of predictions. There are four of these booklets known as series A, N, P and T. Series A contains predictions for circuits in Australia, N for circuits in and from New Zealand, P for circuits from Australia to overseas terminals and T for Papua New Guinea.

TABLE 5-2. FREQUENCY SELECTION URRL FORM

Frequency Predictions for Circuit									Perth District								Date					April 1980			
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
U	10	10	10	10	10	10	10	10	10	10	10	7	7	5	5	5	R	R	R	R	3	3	3	5	10
R1	7	7	10	10	10	10	10	10	10	10	7	7	5	5	5	3	3	3	3	3	3	3	3	5	7
R2	5	5	7	7	7	7	7	7	7	7	5	5	3	3	3	2	2	2	2	2	2	2	2	3	5
L	2	2	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Frequency Predictions for Circuit									Perth- Kalgoorlie								Date					April 1980			
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
U	10	10	10	10	10	10	10	10	10	10	10	10	7	7	7	5	5	5	5	5	5	5	5	10	10
R1	10	10	10	10	10	10	10	10	10	10	10	10	7	7	7	5	5	5	5	5	5	3	5	7	10
R2	7	7	7	7	7	7	7	7	7	7	7	5	5	5	3	3	3	3	3	3	3	2	3	5	7
L	3	5	5	5	5	5	5	5	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
Frequency Predictions for Circuit									Perth-Carnarvon								Date					April 1980			
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
U	10	15	15	15	15	15	15	15	15	15	15	10	10	10	7	7	7	7	7	5	5	5	5	10	10
R1	10	10	15	15	15	15	15	15	10	10	10	10	7	7	7	5	5	5	5	5	5	5	5	7	10
R2	7	7	10	10	10	10	10	10	7	7	7	7	5	5	5	3	3	3	3	3	3	3	3	5	7
L	3	5	5	5	5	5	5	5	5	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
Frequency Predictions for Circuit									Perth-Pt Hedland								Date					April 1980			
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
U	15	15	15	15	15	15	15	15	15	15	15	15	15	10	10	101	10	10	10	7	7	7	7	15	15
R1	10	10	10	10	10	10	10	10	10	10	10	7	7	7	7	5	5	5	5	2	2	2	2	3	10
R2	10	10	10	10	10	10	10	10	10	10	10	7	7	7	7	5	5	5	5	3	3	3	3	7	10
L	5	5	5	5	5	5	5	5	5	5	2	2	2	2	2	2	2	2	2	2	2	2	2	3	5
Frequency Predictions for Circuit									Perth-Kununurra								Date					April 1980			
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
U	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	10	10	10	10	10	10	15	15
R1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7	7	10	15	15
R2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7	7	7	7	7	7	5	5	7	10	10
L	7	7	7	7	7	7	7	7	7	5	2	2	2	2	2	2	2	2	2	2	2	2	2	7	7

521. **Interference Predictions.** During the years, around sunspot minimum, the range of frequencies available for use on a point-to-point circuit is severely limited. Thus, careful frequency usage planning is very important and ionospheric predictions have an important role in this. This is also the period when the recurrent disturbances occur. These further restrict the frequency range by depressing the MUR Fortunately, it is possible to forecast the occurrence and duration of these fairly accurately and even give reasonable estimates of their severity. When the solar indices rise towards maximum, the range of usable frequencies increases and the recurrent disturbances are replaced by the shorter, sudden storms. It might seem that the need for careful frequency usage planning has passed until the next sunspot minimum approaches. However, although the range of usable frequencies on a circuit will increase, the range of interference increases. Not only will other operators start using the higher frequencies but also, unwanted signals will be received from more remote transmitters than at sunspot minimum.

SECTION 5–3. PATH-LOSS PREDICTIONS

522. The IPS also produces path-loss predictions and noise/path-loss predictions in the form shown in Tables 5–3 and 5–4.

523. The path-loss prediction gives the predicted path-loss over a particular circuit, for a given frequency set, using the IF, 2E and 2F modes. It also gives the path length, azimuths, vertical angle range for each mode and the percentage of time that the predicted losses will occur.

524. To use the path-loss prediction, the radio path capability (RPC) of the particular radio equipment must be known. The RPC of an equipment is the amount of loss that can be accepted between the transmitter and receiver at each end of a radio path and it can be calculated from the following formula:

$$\text{RPC} = 10 \log \frac{\text{Tx Power (in watts)}}{\text{Rx Sensitivity (in watts)}}$$

where: Tx = transmitter

Rx = receiver

Table 5–5 gives the RPC for the AN/GRC-106 and the PRC-F1 equipments.

RESTRICTED

TABLE 5-3. PATH-LOSS PREDICTIONS (IN DECIBLES) WITH PROBABILITY DECILE RANGES AND OPTIMUM WORKING FREQUENCIES (MHz)

KEY - DECILE RANGES -A > 90% > B > 80% > C > 70% > D > 60% > E > 50% > F > 40% > G > 30% > H > 20% > I > 10% > J

CIRCUIT MELBOURNE - PERTH — LENGTH 2722 kms — AZIMUTHS 112.0 275.1 — DATE MARCH 1984

FREQUENCY SET 28.0 25.0 21.0 18.0 15.0 12.0 9.0 6.0 3.0

IF MODE	VERTICAL ANGLE RANGE 3 – 9 DEGREES																							
	UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	OWF	17.0	17.9	18.5	18.9	19.3	18.6	18.0	18.0	17.9	16.7	14.5	12.6	11.1	10.0	9.7	9.4	9.2	8.7	8.6	7.9	7.4	8.6	12.8	16.0
	FREQ																								
	25.0	0	130I	131I	131H	131G	131H	130H	129H	128H	127H	127I	0	0	0	0	0	0	0	0	0	0	0	0	0
	21.0	128E	129D	130C	131C	131B	130C	129C	128C	127C	126D	126F	127I	0	0	0	0	0	0	0	0	0	0	0	127H
	18.0	128B	130B	131A	132A	132A	131A	130A	128A	126B	124B	123C	124E	126H	0	0	0	0	0	0	0	0	0	126I	126C
	15.0	133A	137A	139A	141A	141A	138A	134A	130A	126A	123A	122B	122C	123D	125G	125I	125I	125I	0	0	0	0	0	124C	127A
	12.0	146A	0	0	0	0	0	0	142A	130A	122A	120A	121A	121B	121C	121D	122D	122E	123F	123F	123H	123I	123G	124A	134A
	9.0	0	0	0	0	0	0	0	0	0	125A	118A	118A	119A	119A	119A	119A	119A	119B	119B	118B	119C	119C	132A	0
	6.0	0	0	0	0	0	0	0	0	0	0	116A	116A	116A	116A	117A	117A	117A	117A	116A	116A	117A	116A	0	0
	3.0	0	0	0	0	0	0	0	0	0	0	140A	140A	139A	138A	138A	138A	183A	138A	139A	139A	138A	193A	0	0
2E MODE	VERTICAL ANGLE RANGE 5 – 7 DEGREES																							
	UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	OWF	12.7	14.0	14.7	15.1	14.9	14.3	13.4	12.1	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	10.8
	FREQ																								
	15.0	0	0	149H	147E	148F	149I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12.0	139A	140A	141A	142A	142A	141A	140A	139D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9.0	137A	141A	143A	144A	144A	142A	140A	140A	136A	134A	0	0	0	0	0	0	0	0	0	0	0	0	0	134A
	6.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130A	0
2E MODE	VERTICAL ANGLE RANGE 15 – 26 DEGREES																							
	UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	OWF	12.2	12.8	12.9	13.1	13.4	12.9	12.4	12.4	12.5	11.7	10.2	8.8	7.9	7.4	7.0	7.1	6.9	6.6	6.5	6.0	5.9	6.1	8.0	11.5
	FREQ																								
	18.0	0	0	134J	134I	134I	134I	0	132J	131I	130I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15.0	132F	134D	134D	135D	135C	133D	132D	130D	129E	128G	0	0	0	0	0	0	0	0	0	0	0	0	0	131I
	12.0	133A	135A	136A	137A	137A	136A	134A	132A	130A	127B	125C	126E	127E	127J	0	0	0	0	0	0	0	0	0	131B
	9.0	158A	0	0	0	0	0	0	147A	131A	126A	124A	124B	124B	124C	125D	125E	125F	125G	125G	125I	125I	125I	128C	135A
	6.0	0	0	0	0	0	0	0	0	0	132A	121A	121A	121B	122A	122A	122A	122A	122A	122A	122A	122A	122B	123A	147A
	3.0	0	0	0	0	0	0	0	0	0	0	121A	120A	120A	120A	120A	120A	120A	120A	120A	120A	120A	0	0	0

TABLE 5-4. NOISE/PATH–LOSS PREDICTIONS WITH DECLINE RANGES AND OPTIMUM WORKING FORCE FREQUENCIES (MHz)

KEY - DECILE RANGES -A > 90% > B > 80% > C > 70% > D > 60% > E > 50% > F > 40% > G > 30% > H > 20% > I > 10% > J

CIRCUIT MELBOURNE - PERTH — LENGTH 2722 kms — AZIMUTHS 112.0 275.1 — DATE MARCH 1984

FREQUENCY SET 28.0 25.0 21.0 18.0 15.0 12.0 9.0 6.0 3.0

IF MODE	VERTICAL ANGLE RANGE 3 – 9 DEGREES																							
	UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	OWF	17.0	17.9	18.5	18.9	19.3	18.6	18.0	18.0	17.9	16.7	14.5	12.6	11.1	10.0	9.7	9.4	9.2	8.7	8.6	7.9	7.4	8.6	12.8	16.0
	FREQ																								
	25.0	0	52I	51I	51H	51G	51H	52H	53H	54H	55H	54I	0	0	0	0	0	0	0	0	0	0	0	0	0
	21.0	52E	51D	50C	49C	49B	50C	51C	50C	48F	51I	0	0	0	0	0	0	0	0	0	0	0	0	0	53H
	18.0	49B	47B	46A	45A	42A	42A	43A	42A	43B	45B	43C	45E	43H	0	0	0	0	0	0	0	0	0	52I	51C
	15.0	37A	35A	33A	29A	28A	30A	34A	34A	36A	40A	38B	39C	38D	34G	37I	42I	42I	0	0	0	0	0	48C	43A
	12.0	16A	0	0	0	0	0	0	21A	29A	36A	37A	35A	35B	33C	35D	38D	38E	37F	39F	41H	41II	41G	40A	28A
	9.0	0	0	0	0	0	0	0	0	0	29A	36A	33A	32A	30A	30A	33A	33A	33B	34B	36B	35C	37B	24A	0
	6.0	0	0	0	0	0	0	0	0	0	0	36A	32A	32A	30A	37A	27A	27A	28A	28A	28A	27A	32A	0	0
	3.0	0	0	0	0	0	0	0	0	0	0	8A	3A	2A	0A	-3A	-2A	-2A	-1A	-3A	-4A	-3A	-0A	0	0
2E MODE	VERTICAL ANGLE RANGE 5 – 7 DEGREES																							
	UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	OWF	12.1	13.3	14.0	14.3	14.2	13.6	12.7	11.5	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	1.3	
	FREQ																								
	15.0	0	0	23H	23E	21F	19I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12.0	23A	28A	28A	26A	24A	24A	25A	24D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9.0	16A	20A	23A	22A	21A	23A	25A	27A	23A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19A
	6.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20A	0
2E MODE	VERTICAL ANGLE RANGE 15 – 26 DEGREES																							
	UT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	OWF	12.2	12.8	12.9	13.1	13.4	12.9	12.4	12.4	12.5	11.7	10.2	8.8	7.9	7.4	7.0	7.1	6.9	6.6	6.5	6.0	5.9	6.1	8.0	11.5
	FREQ																								
	18.0	0	0	43J	43I	40I	39I	0	38J	38I	39I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15.0	38F	38D	38D	35D	34C	34D	35D	32D	32D	34E	32G	0	0	0	0	0	0	0	0	0	0	0	0	39H
	12.0	29A	33A	33A	31A	29A	29A	31A	31A	29A	31B	32C	30E	29H	27J	0	0	0	0	0	0	0	0	0	31B
	9.0	-4A	0	0	0	0	0	0	16A	26A	28A	30A	27B	27B	25C	24D	27E	27F	27G	28G	29I	29I	31I	28C	18A
	6.0	0	0	0	0	0	0	0	0	0	20A	31A	27A	27A	24A	22A	22A	22A	23A	22A	22A	22A	25A	3A	0
	3.0	0	0	0	0	0	0	0	0	0	0	27A	23A	21A	18A	14A	15A	15A	16A	15A	14A	14A	0	0	0

TABLE 5–5. RPC FOR AN/GRC 106 AND PRC F1

Serial	*Equipment*[1]	*Mode*	*RPC (dB)*
(a)	*(b)*	*(c)*	*(d)*
1	AN/GRC-106 CW	SSB/AM 170	173
2	PRC-FI (Hi Power) CW	SSB/AM 150	153
3	PRC-Fl (Lo Power)	ALL	143

525. For a circuit to work, the following formula must be true:

RPC + antenna gains – fade margin > predicted path-loss

eg: For a circuit from Melbourne to Perth using a AN/GRC-106 with the AN/GRA-50 antenna and a required fade margin of 20 dB:

From Table 6, RPC = 173 dB

AN/GRA-50 gain is 2, ∴ total antenna gain = 4 dB

RPC + antenna gains – fade margin = 173 + 4 – 20 = 157 dB

This can now be compared to the path-loss prediction chart (Table 8) to see if the shot will work and what frequency is the most suitable.

526. The noise/path-loss prediction chart is used with the formula:

$$Pt + Ga = (S/N)_{bHz} - (N/P)_{1Hz} + B \text{ (dBW)}$$

where: Pt = input power to transmitting antenna

Ga = antenna gains

S/N = signal-to-noise ratio for receiver bandwidth bHz

N/P = noise/path-loss from chart

B = 10 log b, where b is the receiver bandwidth

This formula can be used in two ways:

a. If the right hand side of the equation is given, then the antenna gain and transmitter power can be traded against each other (less efficient antennas or lower power radio equipment may be used).

b. If the left hand side of the equation is fixed, then the expected availability and grade of service can be determined.

1. For full description of electronic equipment designators, see *Australian Joint Services Glossary JSP (AS)101* under the term ‘electronic equipment designators’.

SECTION 5–4. DISTURBANCE WARNINGS

General

527. In addition to regular ionospheric forecasts, the IPS is also responsible for issuing ionospheric disturbance warnings. The regular predictions are for normal ionospheric conditions, as the ionosphere responds to the daily, seasonal and sunspot cycle variations in the ionising radiation incident on it, and to the slowly varying component owing to the passage across the sun's disc of emitting regions ("hot spots"). There is also some ionisation from particles, as distinct from electromagnetic radiation.

528. As well as the regular ionospheric variations, there remain other variations, some of them very large, which occur when the ionosphere is disturbed by the effects of solar activity and magnetic storms, and there is a need, both in HF radio communications and for other purposes, for forecasts and confirmation of these events. The IPS Disturbance Warning Section provides warning messages which cover daylight fadeouts, polar cap absorption (PCA) and the geophysical disturbances which are observed at the earth's surface as magnetic storms. On rare occasions, the solar particle flux causing a PCA is so energetic that it could be dangerous to astronauts and to supersonic aircraft operations, and may be observed at ground level as solar cosmic rays.

Disturbances and Effects

529. A daylight fadeout is a sudden, partial or complete absorption of signal on the sunlit side of the earth, more severe at the lower frequency end of the available band, on circuit paths near the equator, and near the noon meridian at fadeout time.

530. Ionospheric disturbances accompany magnetic storms. They are more severe at night and away from the equator, and affect the higher frequencies more than the lower. Magnetic storms, recorded at ground level, are the combined effects of currents in the earth, in the ionosphere and in space around the earth. They are caused by any of the following:

a. The arrival of plasma clouds from the sun, which produce sudden, severe disturbances of one to three days' duration. They are normally associated with sunspots and flares.

b. Persistent streams in the solar wind.

c. Coronal hole disturbances, which commence more gradually and are less severe but are of longer duration. They are not associated with sunspot activity and they tend to recur with the 27 day variation.

531. PCA events, also called polar blackouts, are similar in eflect to daylight fadeouts, but are confined to the polar regions (geomagnetic latitudes above approximately 65 degrees), and are caused by the arrival in the ionosphere of low energy cosmic rays (particles, mainly protons) from the sun. PCAs begin usually some hours after major flares with particular characteristics but are less frequent than magnetic storms; they can start at any time of the day or night and continue for hours or days. A few times in an 11 -year solar cycle, following proton flares, the flux rises to dangerous levels as already mentioned and special warnings of these events are issued.

The Warnings

532. The Disturbance Warning Section of IPS operates every day, working hours being extended when significant events are thought likely to occur. Each warning carries a serial number and a date-time group. All times of messages and of events mentioned in them are given in Universal Time (UT, GMT, or Z Time). Annex A to this chapter shows some typical disturbance warnings.

533. A warning may contain one or more of the following:

a. A forecast may be included of the occurrence of a significant magnetic disturbance (significant for HF radio communications effects), with an estimate of its expected severity. The messages are issued a few days to a few hours before the event. For flare-associated magnetic storms, the delay between flare and storm may be only a day, while the starting date of a 27-day recurrent disturbance may be affected by the development of coronal holes and changes in the solar wind structure since the previous rotation. Three grades of probability are used, ie, possible, probable and expected, and three levels of intensity, ic, slight, moderate or severe (sometimes very severe).

b. Warning may be given that daylight fadeouts are likely, because of the presence of suitable active regions on the sun.

c. Confirmation may be given of magnetic storms, particularly those which were not forecast, and of major daylight fadeouts, including some which may have been reported from other longitudes during the night hours in Australia. Confirmation of daylight fadeouts actually in progress is sent by special arrangement only to a few users, since a fadeout has usually ended before such a message could be sent in the usual way and acted upon.

d. Information may be provided about solar and geophysical events and as background to the warnings.

Distribution of Warnings

534. Warnings from the IPS are sent to Department of Defence (Central Office). Army distribution is done by DEFCOMMARS MELBOURNE. Warnings should take no more than two hours to be distributed to all addressees. Warnings are also broadcast on the meteorological station AXM. These are radio teletype (ratt) broadcasts, on the hour, on the following frequencies:

a. AXM 32,5.10 mHz, using 5 kW;

b. AXM 34, 11.03 mHz, using 10 kW;

c. AXM 35,13.92 mHz, using 20 kW; and

d. AXM 37,19.69 mHz, using 20 kW.

Coping with Disturbances

535. Since the warnings are basically forecasts of magnetic storms and daylight fadeouts, action to be taken before and during these events is a matter of operating experience according to the circuit path and frequencies available, and should be related to the normal predictions for the same circuits.

536. The ionospheric disturbances which accompany magnetic storms are more severe in high latitudes with a maximum in the auroral zones. As a rule, these are the latitudes first affected. From Australia, the main circuit paths near these zones are to South Africa, South America, and Europe (long route). These paths, and those to Eastern USA, Canada and to Europe (short route), are generally affected earlier and more severely than those confined to lower latitudes or which pass directly across the equator. The equatorial regions are not seriously affected except during the most severe storms. In general, the procedure is to change to lower frequencies. At middle and low latitudes, if it is local daytime when the magnetic storm begins, the MUF may actually increase during the first day and evening.

537. For daylight fadeouts, use higher frequencies, noting that the fadeout may be occurring on the sunlit part of a long path, even though one terminal may be in darkness.

Annex: A. Typical Disturbance Warning

ANNEX A TO
CHAPTER 5 ,

TYPICAL DISTURBANCE WARNING

IPS WARNING NO 74/06 MARCH 08/0130Z
MODERATE MAGNETIC DISTURBANCE EXPECTED LATE MARCH 09 THROUGH 15 APPROX. THE SUN REMAINS QUIET.

(Recurrent disturbance expected: not due to flares.)

IPS WARNING NO 70/22 JULY 22/0120Z
CONFIRM SEVERE FADEOUT 22/0028Z ASSOCIATED WITH SOLAR FLARE STILL IN PROGRESS 01 15Z A SIMILAR BUT LESS SEVERE FADE WAS REPORTED 20/1119Z FURTHER FADEOUTS EXPECTED NEXT FEW DAYS. LIMITED DATA INDICATE MAGNETIC DISTURBANCE PROBABLE JULY 23.

(Confirming daylight fadeout, where full details of the solar event were not yet available. The magnetic disturbance did not occur - see Warning No 70/23 below.) (Warns of more daylight fadeouts as well as edects of magnetic storm.)

NO 70/22A ABSORPTION AT LOWER FREQUENCIES FOR SHORT PERIODS EXPECTED DURING NEXT FEW DAYS. MUFS WILL BE DEPRESSED FROM JULY 23 IF MAGNETIC STORM OCCURS BUT ANOTHER WARNING WILL BE SENT IN THAT CASE.

IPS WARNING NO 70/23 JULY 24/0610Z
SATELLITE DATA INDICATE THAT DISTURBANCE FROM THE SOLAR EVENT 22/0028Z HAS MISSED THE EARTH BUT MODERATE TO SEVERE MAGNETIC DISTURBANCE NOW PROBABLE JULY 25 FOLLOWING ANOTHER MAJOR FLARE NEAR THE CENTRE OF THE SUN'S DISC 23/1832Z. MINOR POLAR CAP ABSORPTION STARTED 23/2100Z

NO 70/23A MUFS EXPECTED TO BE DEPRESSED 25TH. ABSORPTION AT LOWER FREQUENCIES FOR SHORT PERIODS ALSO PROBABLE BUT NOT MORE THAN ABOUT ONCE A DAY.

(Confirming no storm from July 22 flare but predicting another one – which did occur. Mentions absorption in polar regions due to fast particles from the flare.)

IPS WARNING NO 70/07 FEBRUARY 19/0600Z
CONFIRM FADEOUT 19/0330Z ASSOCIATED WITH MINOR SOLAR FLARE. MORE DAYLIGHT FADEOUTS EXPECTED NEXT FEW DAYS. MAGNETIC DISTURBANCE NOT EXPECTED AT PRESENT.

(Solar activity but no disturbance expected.)

ANNEX A 5A – 2

CHAPTER 6

HF FREQUENCY ASSIGNMENT

SECTION 6–1. TENETS OF FREQUENCY MANAGEMENT

Introduction

601. Frequency management is dealt with in *RA Sigs CTN 3. 1, Frequency Management,* which also covers frequency assignment in more detail. This chapter gives an overview of frequency management, with emphasis on practical frequency assignment.

602. The RF spectrum is a limited resource which must be shared by civil, government and military users in both peace and war. It is essential to the efficiency of the military communications system that sound tenets of frequency management be employed.

RF Management

603. RF management is the process of planning and controlling the electromagnetic spectrum. It includes the functions of RF allocation and assignment.

RF Allocation

604. RF allocation is the planning process by which RF bands or specific frequencies are designated for use in performing specific functions. In Australia, the responsibility of frequency allocation is exercised by the Department of Communications in the first instance. Allocation of frequencies for the Department of Defence is coordinated by DWCE.

RF Assignment

605. RF assignment is the process of designating specific RFs or frequency bands for use at a particular station under specific operating conditions.

SECTION 6–2. FREQUENCY SHARING

606. Two systems exist for sharing frequencies:

a. the regional system, and

b. the list system.

The Regional System

607. The regional system is used where there is a low concentration of troops over a large area. The area of operations is divided into regions and blocks of frequencies are assigned as follows:

a. Block A is for:

(1) operational headquarters,

(2) inter-regional links, and

(3) operational troops.

b. Blocks B, C and D are for use with transmitter powers over 100 watts and are repeated every fourth region.

c. Block E is for use with transmitter powers of less than 100 watts and is used in every region.

608. The advantage of this system is that each list contains a large number of frequencies and imparts flexibility within each region.

609. The main disadvantage of the system is that it does not allow for the concentration of troops into one region at short notice.

The List System

610. The list system consists of three lists of frequencies for each type of major formation and headquarters. These lists are repeated geographically at every fourth formation or headquarters of the same type.

611. When working with other formations, there are insufficient frequencies to assign exclusive frequencies to each formation. Common lists are, therefore, prepared for each type of major formation and these are used by each formation in addition to its exclusive list.

612. Lists are compiled from master registers and are sent to units through normal channels. All frequencies have a power limitation and a selection of suitable frequencies is included in each list.

613. The categories of transmitting power for this purpose are classified as:

a. P1, not exceeding 3 watts;

b. P2, not exceeding 25 watts;

c. P3, not exceeding 100 watts;

d. P4, not exceeding 500 watts; and

e. P5, powers over 500 watts.

614. The advantages of the list system are as follows:

a. It will work with a large concentration of troops.

b. It can cope with an indefinite number of formations.

c. It is flexible when formations are being regrouped.

615. The disadvantages of the system are as follows:

a. There is little flexibility within formations, owing to the small number of frequencies in each list. This is aggravated by the power restrictions imposed on particular frequencies.

b. It gives no protection against sky wave interference from other Army stations in the theatre.

Frequency Assignment at HF

616. The data required in order to commence the assignment of frequencies includes:

a. formation order of battle;

b. tactical groupings for future operations;

c. a comprehensive radio diagram of every net in the formation;

d. a list of nets showing the power employed;

e. the frequency list allotted by higher formation, including power restrictions;

f. a list of frequencies allotted by a higher formation to lower formations or Army troops in the higher formation's area;

g. a list of intermediate frequencies of the receivers used;

h. a list of known bad frequencies; and

i. ground and sky wave charts for the theatre.

617. It is absolutely essential, particularly at HF, that a system of priorities be established for the purpose of frequency allocation. Where large numbers of radio terminals are located in close proximity, it may not always be possible to assign non-interfering frequencies to all users.

618. There are some links which, by their very nature, are extremely inflexible and generally use fixed frequencies. Examples of these are emergency services, international distress and air traffic control frequencies. HF circuits employing sky wave fall into this category and should be given priority. The tactical situation will, to a large extent, decree priorities. Obviously, the Tactical Air Request (TAR) and other such nets could be high on the list. As a general rule, trunk circuits have a higher priority than single channel circuits for the purpose of frequency allocation.

Mutual Interference

619. Even with the most careful preparation, not all interference sources will be discovered in advance. It is necessary to have a detachment for locating sources of interference. Monitoring stations can occasionally identify the interfering station and locate it by its transmitted call Agn. In other cases, it may be necessary to pass the information available (such as the frequency and the time that interference is usually encountered), to a direction-finding station for location of the interfering station. Reports sirbuld go to an appropriate headquarters to resolve the problem and to enford frequency discipline.

620. To overcome some of the problems of mutual interference, the following rules are helpful:

a. Common list frequencies should be assigneo to the lower priority nets.

b. Alternative frequencies should be assigned to the higher priority nets.

c. Some good frequencies must be kept as spares.

Intermodulation

621. Intermodulation between radio frequencies can occur in radio transmitters when some of the power from one transmitter is coupled to the output circuit of another. The intermodulation occurs because of coupling between transmitting antennas and/or transmission lines, or in other ways. New and unwanted output frequencies are generated and radiated; these new frequencies may be picked up on nearby receiving antennas.

622. When the number of transmitters is increased, the number of possible intermodulation frequencies increases rapidly. The most serious of these frequencies are third-order products of the form 2A – B or A + B – C, where A, B and C are operating frequencies of three transmitters. The results of this intermodulation are likely to be greatest when all or several of the frequencies, both transmitting and receiving, are close together. In this case, the ability of transmitters, receivers, and antennas to reject the unwanted transmissions is poor.

623. The effects of intermodulation distortion can be minimised by careful frequency assignment. This includes the following considerations:

a. *Wider Channel Spacings.* Usually it is not necessary to crowd the frequencies together. Crowding increases the likelihood of interference through the lack of selectivity in the radio equipment or because of spurious output and response.

b. *Choice of Specific Frequencies.* Frequencies should be selected so that the frequency difference between any pair of frequencies is unlike the difference between any other pair. In some cases, the specific operating frequencies can be chosen so that no third-order product frequency coincides with a receiving channel frequency at the same time or a nearby site. Frequencies selected in this manner may result in a setup that is inflexible.

c. *Wide Frequency Separation.* For duplex operation, provision should be made for wide frequency separation between any transmitting frequency and any receiving frequency at the same site. However, widely separated frequencies are not always available.

Interference Charts

624. An example of a mutual interference chart for HF links is included as Annex A to this chapter. This is not the only format that can be employed, and users may develop other techniques to simplify the process.

625. Information from the mutual interference chart may be entered on to a matrix for easy reference. An example of the matrix is in Annex B. The shaded squares show mutually interfering frequencies.

626. The information in the matrix assists in compilation of a plan to assign frequencies against priorities.

Frequency Assignment for Tactical Radio Nets

627. The Frequency Assignment for Tactical Radio Nets (FASTNET) computerised Signal Operation Instructions (S01) system is a series of linked computer programs developed to provide divisional and Field Force units with an automated facility that will produce a complete SOI containing HF, VHF and UHF frequency assignments and all other necessary information required in an SOL

628. Information which is required before entering any information into the computer includes.,

a. the number of frequencies and bands required by each net;

b. the location of each station on each net, for the purpose of considering whether any nets need co-site information to be placed in the computer;

c. the number of frequencies required for the job; and

d. Ionospheric Prediction Service (IPS) chart information for the various locations.

629. Before entering any net or frequency data into the computer, the following information is required to be entered in for HF, VHF and UHF bands:

a. separation required between frequencies on the same net, eg, Priority and Alternate;

b. separation required between frequencies on the same site, eg, cositings;

c. separation required between a frequency and a harmonic;

d. separation required between frequency and an intermodulation;

e. the requirement to consider:

(1) second signal third-order intermodulation,

(2) second signal fifth-order intermodulation,

(3) third signal third-order intermodulation; and

f. which UHF interference equation is to be chosen from the grouping FM 1 to 4 (1 being the greatest possibility of interference, and 4 being the least).

630. Due to the number of frequencies available, paragraph 629.e is normally answered with 'NO' while paragraph 629.f is answered with 'ONE'.

Annexes: A. Example of a Mutual Interference Chart for HF Links

B. Frequency Assignment Matrix

TABLE 6–1. EXAMPLE OF A MUTUAL INTERFERENCE CHART FOR HF LINKS

Serial	*Operating Frequency*	*2nd Harmonic (2fn kHz)*	*Image Frequency (F(I) = Fn + 2IF)*	*Image Frequency (F(I) = Fn - 2IF)*	*Causes Inter-ference to:*	*Recieves Inter-ference from:*	*Remarks*
(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*	*(h)*
1	2428	4856	3348	1508	Serial 5 & 6	Serial 2	5 – 2nd Harmonic 6 – 2nd Harmonic 2 – 2nd Channel
2	3350	6700	4270	2430	Serial 1	Serial 1	1 – 2nd Channel
3	4470	2940	5390	3550	Serial 22		22 – 2nd Harmonic
4	4660	9320	5580	3740			
5	4850	9700	5770	3930	Serial 6	Serial 5 & 1	)1 – 2nd Channel) Adjacent channel) if sited together
6	4860	9720	5780	3940	Serial 5	Serial 6 & 1	1 – 2nd Channel
8	8945 etc	17890 etc	9865 etc	8025 etc		Serial 3 etc	3 – 2nd Harmonic etc

Note: (1) IF, Intermediate Frequency = 460 kHz

ANNEX B TO
CHAPTER 6

FREQUENCY ASSIGNMENT MATRIX

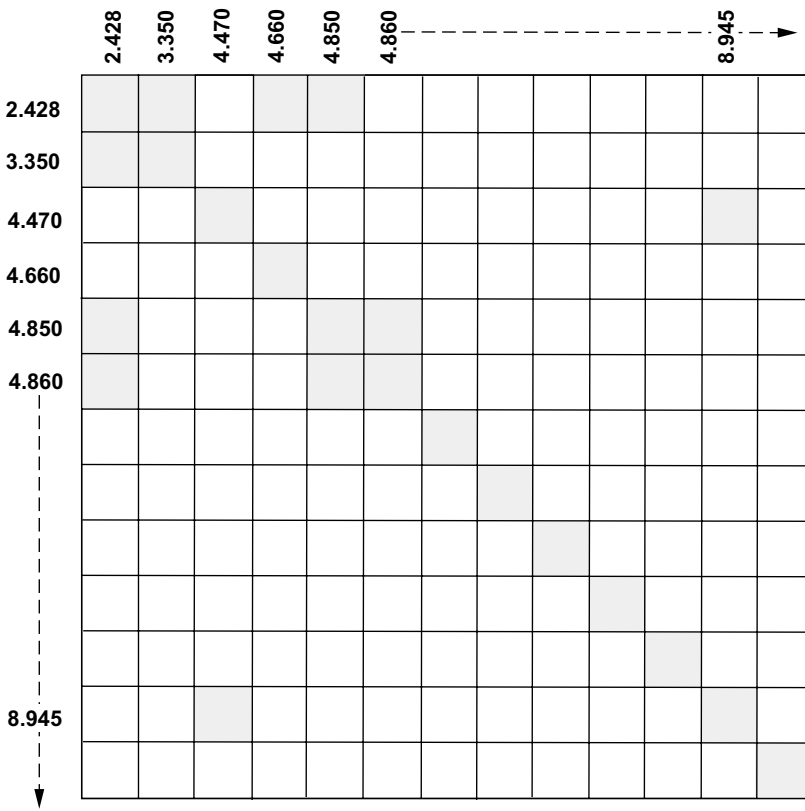


Figure 6–1. Frequency Assignment Matrix

CHAPTER 7

PRACTICAL ANTENNAS

SECTION 7–1. INTRODUCTION

701. This chapter deals with the design and construction of specific antenna types suitable for employment with field communications, and includes the range of antennas associated with low powered field radios through to the types of antennas associated with high powered radios which may be deployed into the field.

702. As this chapter deals only with a selection of field antenna types, a more detailed coverage of antennas may be obtained from *MLW 2, Sigs Trg* 4. *1, Antenna Handbook*.

SECTION 7–2. BASIC FIELD ANTENNAS

Vertical Whip/Wire Antennas

703. Vertical antennas are generally adaptable to any frequency band merely by using the correct physical size to produce the desired propagational pattern. For example, criteria set for whip antennas in the HF band are applicable to tower and mast antennas in the medium frequency.

704. The majority of HF short distance field radio systems are mobile. This means that an antenna must be used which will transmit and receive equally well in all directions in the horizontal plane. A vertical whip or wire fulfills this requirement.

705. The ideal practical length (L) for a normal HF vertical whip or wire is a quarter wavelength. This length is given by the formula:

$$\text{L (metres)} = \frac{71.25}{f}$$

where f = frequency in MHz

The ideal practical length of a quarter wavelength whip at a frequency of 5 MHz is $\frac{71.25}{f}$ m or 14.25 m.

706. When whip antennas are operated in the HF range, their lengths are usually a small fraction of a wavelength. In this case, loading coils must be used to resonate the whip antenna properly (usually incorporated within field

radio equipments). The radiation resistance of a short whip is very low and it is quite possible that the ohmic losses which result from the resistance of the loading coil, antenna connection and the antenna itself, may exceed the radiation resistance. The radiation efficiency of this antenna is low, being approximately 0.5 to 2 per cent in the low end of the HF band. If large whips or even higher frequencies are used, so that the whip is a quarter or half wave-length long, the efficiency of the antenna increases. A 4 m whip, for example, is a quarter wavelength at approximately 18 MHz.

707. In the VHF band (and higher), short whip antennas with lengths of a quarter and a half wavelength can be readily provided; under these conditions, high radiation efficiencies are possible.

708. Figure 7–1. gives an indication of average efficiencies for a 4.5 m and a 1.2 m whip antenna over the frequency range of 2 to 30 MHz.

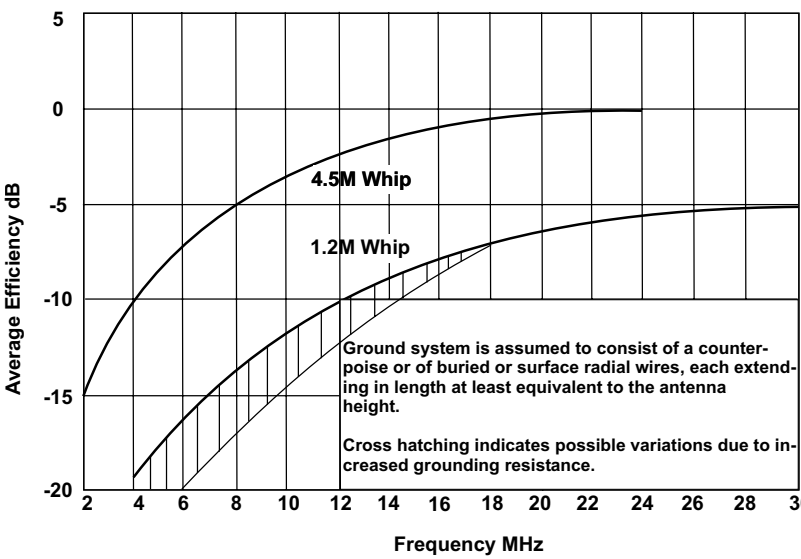


Figure 7–1. Average Efficiencies of 4.5 and 1.2 m Whip Antennas in the 2 to 30 MHz Band

709. In a static environment, a quarter wavelength vertical wire antenna will eliminate many of the problems associated with an electrically short whip described in paragraph 706. Typical supports for this antenna include trees, telegraph poles or buildings. Trees or buildings will, however, absorb some of the radiated signal and screen the antenna. Therefore, the radiating element should be, if possible, at least 30 m away from this type of support (Figure 7–2).

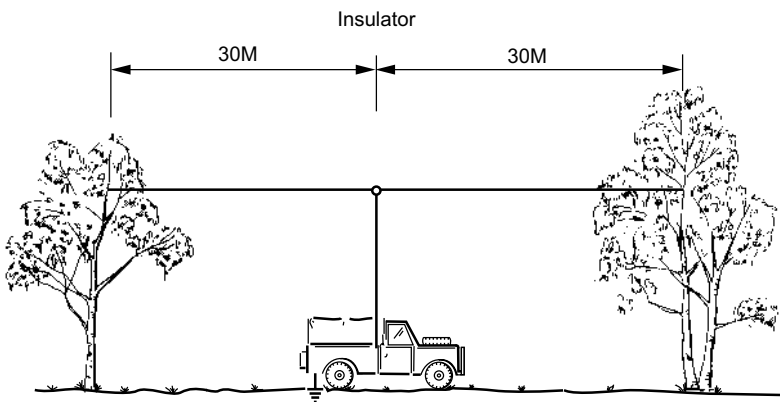


Figure 7–2. The Vertical Quarter Wave Antenna Constructed of Wire Using Two Trees for Support

Sloping Whip/Wire Antennas

710. Generally speaking, sloping whip or wire antennas show the same characteristics as their vertical counterparts, but are more efficient for the same vertical height because a greater length can be obtained.

711. The sloping antenna also produces a sky wave radiation component as well as a ground wave component, the actual ratio depending upon the angle of slope. It also produces maximum efficiency when a quarter wave-length long.

712. This arrangement shows some directional characteristics in that minimum signal is radiated in the direction of the slope of the whip or wire (Figure 7–3).

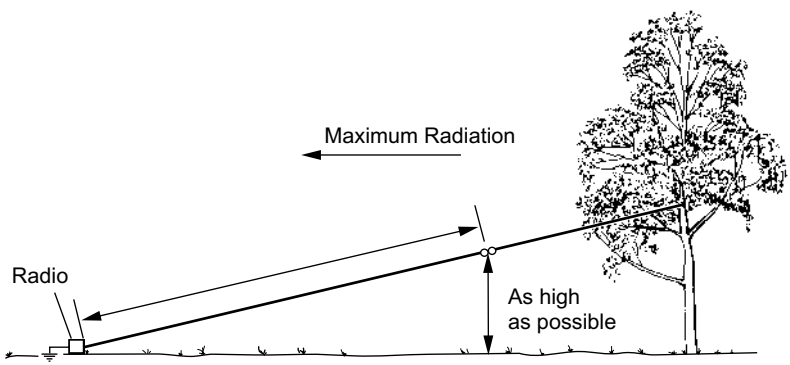


Figure 7–3. The Sloping Whip/Wire Antenna

The Inverted 'L' Antenna

713. If the supports are not high enough to allow a full quarter wave vertical wire to be erected, the top may be bent over horizontally. The antenna then resembles an inverted 'L'. Because the nature of a quarter wave antenna is such that it carries most current and radiates most strongly from the portion nearest the feed point, it is preferable to bend over the top rather than increase loading at the bottom.

714. The overall length of the inverted 'L', ic, a + b (Figure 7–4), should be a quarter wavelength (or as near as possible). Some loading is always necessary.

715. When using the inverted 'L' antenna for ground wave communication, the dimension 'a' should be as long as possible. The antenna is more efficient than a vertical whip or wire for the same height but care should be taken over selection of supports.

716. The horizontal portion of the antenna radiates sky waves and, if the frequency is low enough, interference between sky and ground waves can occur, particularly at the limit of the ground wave range. To reduce this effect as far as possible, the horizontal portion of the radiator should be 'end on' toward the distant station.

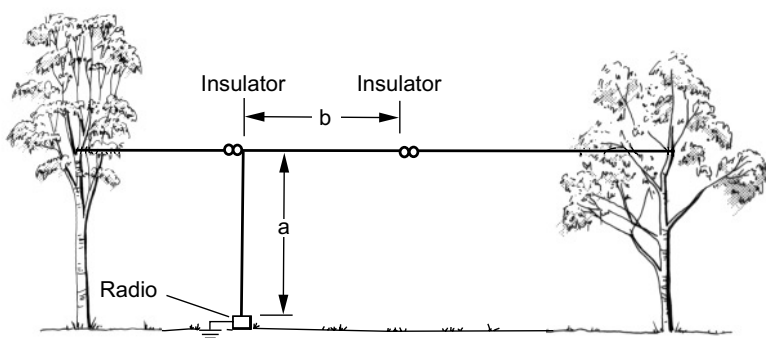


Figure 7–4. The Inverted 'L' Antenna

The 'T' Antenna

717. The 'T' antenna is a development of the inverted 'L'. It has the advantage that the current fed into the top splits half to each side and the sky wave radiation cancels itself out. It is a very efficient antenna and should be employed in preference to the inverted V when only ground wave radiation is required (Figure 7–5).

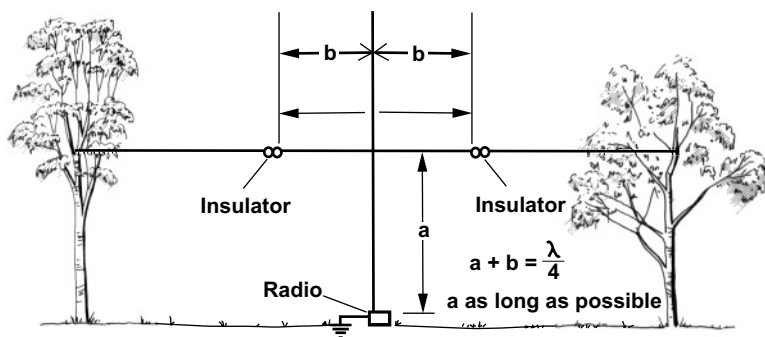


Figure 7–5. The 'T' Antenna

718. The length of the vertical part (a) plus half the horizontal part (b) should be a quarter wavelength. For very low frequencies, the length (a) should be as long as possible and the length (b) should not exceed twice (a).

The End-fed Antenna

719. The end-fed antenna is a sky wave derivation of the ground wave inverted 'L' and sloping wire antennas. There are four basic forms of the end-fed antenna:

a. ¾, wavelength (Figure 7–6);

b. ⅝ wavelength;

c. ¼ , wavelength; and

d. sloping (Figure 7–7).

720. In the case of the horizontal end-fed antennas, radiation is predominately sky wave (the horizontal portion being much longer than the vertical). Best efficiency is obtained from the ¾ wavelength end-fed while the others operate with decreasing efficiency.

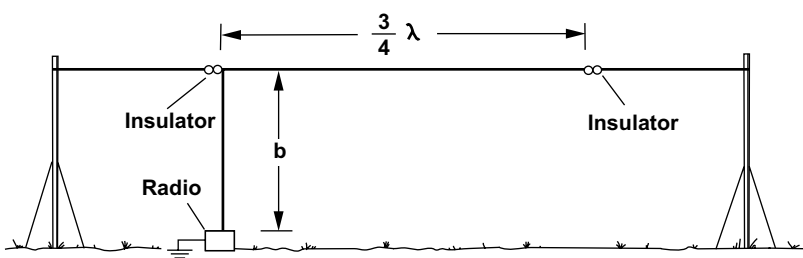


Figure 7–6. The ¾, Wavelength End-fed Antenna

721. For convenience of construction, the horizontal end-fed antenna can be erected as a sloping wire. The far end should be attached via insulators to a support about 3 m high. This antenna displays properties similar to the sloping wire described previously, except that, since the far end is closer to the ground (ie, the wire is nearly horizontal), radiation will be predominately sky wave. The efficiency of this antenna is low.

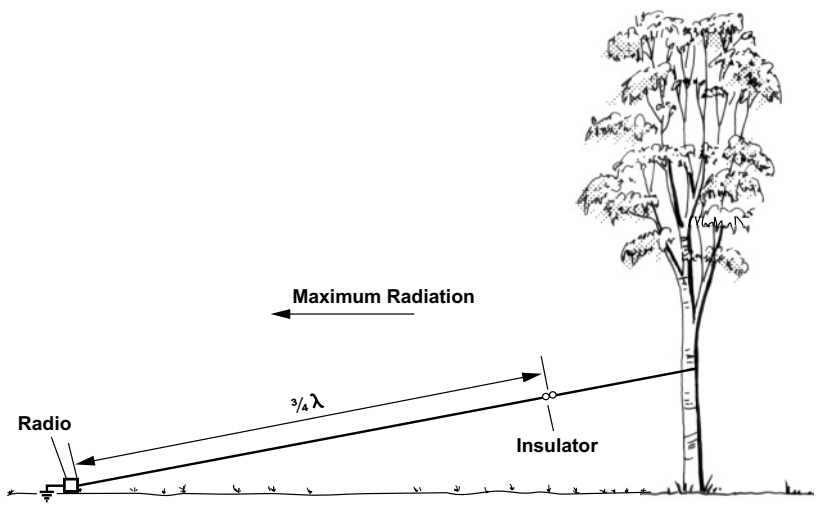


Figure 7–7. The Sloping End-fed Antenna

Horizontal Half Wave Dipoles

722. The basic half wave antenna is one of the simplest and most fundamental of the radiating systems in common use. Geometrically, this antenna is a simple linear element which has an electrical length of one half wavelength. Normally, the radiator is a thin wire, but conductors of a smaller length-to-diameter ratio are sometimes used for applications which require slightly wider bandwidth (Figure 7–8). It is important that a balanced feed be employed on this antenna, so that the current in each element is equal but opposite.

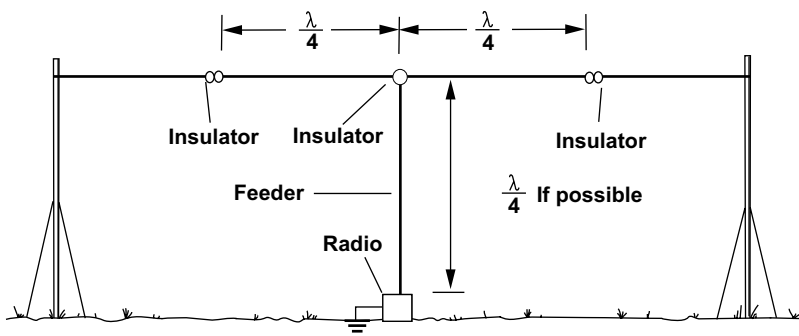


Figure 7–8. The Half Wave Dipole

Vertical Half Rhombic/Inverted Vee

723. The basic inverted vee antenna is highly directional. It is vertically polarised and can be used for space and surface wave propagation. Dimensions for the antenna are:

$$l = \frac{h^2 f(\text{MHz})}{213.75} + \frac{55.64}{f(\text{MHz})} = \text{m}$$

For greatest efficiency, 'l' should be one half of a wavelength long (paragraph 728). This antenna is generally impractical at frequencies below 10 MHz.

724. This antenna gives greatly improved performance on a one-to-one link. It is not suitable for networking or in jungle or close country (Figure 7–9).

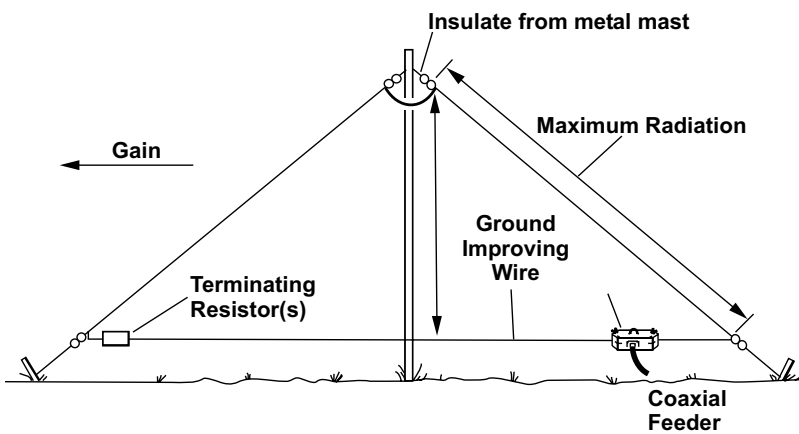


Figure 7–9. The Inverted Vee Antenna

Ground Antenna

725. Maximum radiation is in the direction to which the free end points Radiation is surface wave.

726. Best results are achieved using thin wire, such as single strand enamel-insulated wire. The length is not critical as the antenna is non-resonant. The planning range is as for a 324 cm vertical rod (Figure 7–10).

Figure 7–10. The Ground Antenna

Guide to Selection of Field Antennas

727. It is stressed that Table 7–1 is to be used as a guide only. When selecting a field antenna, the operator must also consider:

a. siting, orientation and elevation of the antenna in relation to the distant stations;

b. the power output of the radio equipment; and

c. the terrain over which he is required to operate.

TABLE 7–1. GUIDE TO FIELD ANTENNA SELECTION

Serial	*Range*	*HF*		
		Directional	*Bi-directional*	*Omnidirectional*
(a)	*(b)*	*(c)*	*(d)*	*(e)*
1	0 to 5 km	1. Ground Antenna 2. Sloping Wire		1. Rod Antenna 2. 'T' Antenna 3. Inverted 'L'
2	5 to 30 km	1. Ground Antenna 2. Sloping Wire		1. 'T' Antenna 2. Inverted 'L' 3. 3/4 Wave End-fed
3	30 to 100 km	Sloping Wire	Dipole	1. 'T' Antenna 2. Inverted 'L' 3. 3/4 Wave End-fed
4	100 to 200 km	Sloping Wire	Dipole	
5	Over 200 km	Inverted V	Dipole	

Formulas for Construction of Field Antennas

728. The formulas for construction of field antennas is as follows:

a. Physical Length:

(1) $1 \text{ Wavelength} = \frac{285}{\text{Freq in MHz}} = 285 \text{ metres.}$

(2) $¾ \text{ Wavelength} = \frac{213.75}{\text{Freq in MHz}} = 213.75 \text{ metres.}$

(3) $½ \text{ Wavelength} = \frac{142.5}{\text{Freq in MHz}} = 142.5 \text{ metres.}$

(4) $¼ \text{ Wavelength} = \frac{71.25}{\text{Freq in MHz}} = 71.25 \text{ metres.}$

(5) $¼ \text{ Wavelength} = \frac{68.6}{\text{Freq in MHz}} = 68.6 \text{ metres.}$

(Braid Antenna).

b. Electrical Length:

$$¼ \text{ Wavelength} = \frac{75}{\text{Freq in MHz}} = \text{metres.}$$

Summary of Field Antennas

729. Generally, the vertical antennas give a good coverage up to about 200 km, depending upon the terrain. Communications over a 24-hour period are more dependable with a vertical than a horizontal antenna because the ground wave, which is the means by which most of the energy is propagated, does not depend upon ionospheric conditions.

730. The horizontal antennas give a longer range than the vertical antenna. The received signal is dependent upon ionospheric conditions, and communications are not as reliable as with a vertical antenna over a 24-hour period. When an antenna is a quarter wavelength above ground, good communications up to 350 km may be expected.

731. Some antennas give both sky and ground wave, thus combining the relative advantages and disadvantages of both. The extreme case of this is the sloping antenna.

732. The antennas covered here are not the only antennas that can be used. This is a selection of the most common antennas used in the Army. These

antennas are fairly efficient under a great variety of conditions. Maximum efficiency occurs when the horizontal section is a quarter wavelength above ground.

733. If communications are poor or if time permits, a number of different antennas should be tried to obtain the best result.

CHAPTER 8

EARTHING TECHNIQUES

SECTION 8–1. INTRODUCTION

801. The purpose of this chapter is to present, in general terms, the various earthing techniques available to the user of communications and electronic equipment. It does not supersede current practices but supplements the detailed earthing procedures found in equipment manuals.

802. One of the most common faults in the use of HF communications is the inadequate earthing of radio equipments, and the resulting loss of efficiency not being recognised by the operator.

803. Earthing is a method of protecting personnel and equipment from electricity and enhances the operating efficiency of the equipment. This chapter covers the three basic earthing techniques:

a. earth ground,

b. equipment ground, and

c. chassis ground.

804. **Earth Ground** Electrical charges can develop in equipment, so there is a need to provide a metal path (earth ground) for these charges to flow harmlessly into the earth.

805. **Equipment Ground** A good equipment ground is needed in order to connect all equipment components to a common earth ground.

806. This type of ground connects the metal frames, cases, dust covers and cable shields of equipment to the earth. It protects operators from electrical shock, and it protects the equipment from being damaged.

807. **Chassis Ground** A chassis ground is used on all electrical equipment and vehicles. Examination of the inside of an Army radio will reveal that some of the parts are connected to the metal chassis (ground).

SECTION 8–2. BASIC EARTHING TECHNIQUES

Grounding Systems

808. The most commonly used grounding systems are explained in greater detail in subsequent paragraphs and include:

a. earth stakes,

b. underground objects, and

c. ground plates.

809. **Earth Stakes** An earth stake is the most often employed earthing system and it is also the most often misused. Issued earth stakes are made of a metal that does not erode or rust easily. Some stakes may be longer or thicker than others, but the earth stake alone will not do the job. Operators need a complete earth stake system, which includes a ground strap (paragraph 810) and a terminal screw (paragraph 812) or clamp (paragraph 813) to connect the strap to the stake. A complete earth stake system is normally issued with the equipment that requires it, installation instructions are provided with the equipment.

810. **Ground Straps** The best type of ground strap is made of braided copper material. If the issued ground strap is lost, it must be replaced with the heaviest gauge wire available. Ground straps must:

a. be kept short,

b. have solid connections, and

c. be kept clean and tidy.

811. **Connections** The ground strap must be connected properly to maintain a good earth. Usually, the equipment has a built-in terminal for connecting the strap. The earth stake will normally have a terminal screw or a ground clamp, or it may be necessary to tightly wrap and secure the straps around the earth stake.

812. **Terminal Screw** The terminal screw is part of the earth stake and it must be tightened properly to hold the ground strap securely against the stake.

813. **Ground Clamps** A ground clamp should only be used if the earthing stake does not have a terminal screw. The clamps come in different shapes and sizes (Figure 8–1) but they all have one purpose, to hold the ground strap tightly against the earth stake.

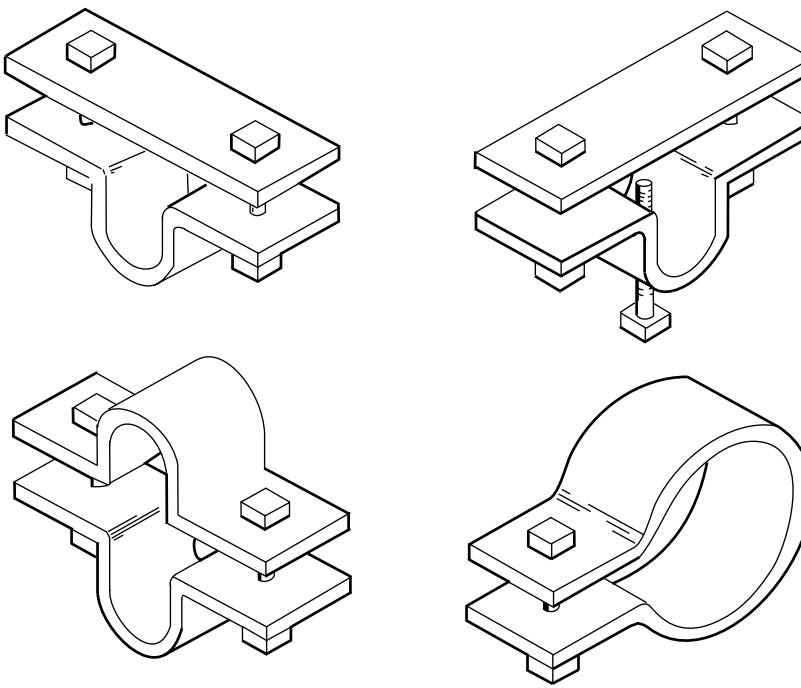


Figure 8–1. Four Types of Ground Clamps

814. **Wrap Method** The wrap method should only be used if a terminal screw or a ground clamp is not available. It is necessary to bind the ground strap to the stake by using strong, flexible bare wire. Approximately 24 turns of the wire around the strap and the stake should be sufficient. If solder cannot be used, the wire must be twisted as tightly as possible, without breaking it, and the connection should be taped to keep out moisture. Irrespective of the method used to connect the ground strap, it must be clean and tight.

Installation

815. The efficiency of the earth system depends on the stake and how it is installed. First, clean the stake to remove any paint, grease or oil from it. It is necessary to get the earth stake into the subsoil to ensure a good ground. Top-soil is generally a poor conductor of electricity so it is necessary to dig a hole about 15 to 20 cm deep and about 45 cm across. This should allow insertion into the subsoil and, at the same time, permit room to work.

816. The way the earth stake is driven into the ground has a direct bearing on how well it will work. Strike the end of the stake just hard enough to drive it into the ground. The lighter the driving blows, the less the soil is disturbed, thus ensuring more direct contact between the stake and the soil.

817. When the top of the stake is about 6 cm. above the bottom of the hole, connect the ground strap to the stake. Fill the hole with water, let it soak in, then fill the hole with dirt. Keep the soil around the stake moist and the result should be an efficient grounding system.

818. When it is time to move equipment, the earth stake is often difficult to remove. Removal of the earth stake is limited only by an operator's imagination and the tools available. Two simple methods of removal are to use a vehicle jack or a ship hammer (Figure 8–2)

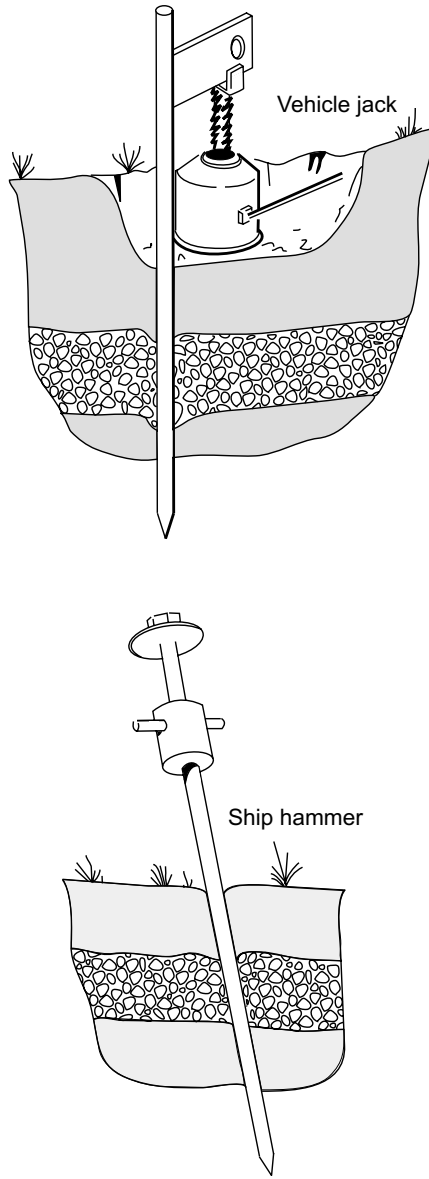


Figure 8–2. Removal Method

Underground Objects

819. If they are buried deeply enough, metal underground objects may provide a reliable, ready-made, earthing system. Items such as buried pipes, steel building frames, metal poles or storage tanks may be used.

WARNING
If an underground pipe or tank is used, ensure that it does not contain gasoline or any other flammable substance.

820. Connect the ground strap to the underground object in the same manner used for an earth stake. In most instances, a clamp or wraparound method will have to be used.

Ground Plates

821. Iff a good ground cannot be obtained with an earth stake or underground objects, it is possible to construct and use a metal ground plate. The plate consists of a metal sheet 1 m x 1 m, with a ground strap secured to the centre of the sheet (Figure 8–3).

822. The best way to secure the ground strap is to drill a hole and fasten the strap with a bolt or screw. After the strap is secured, bury the plate at least 1.2 m deep and keep the soil around the plate moist at all times.

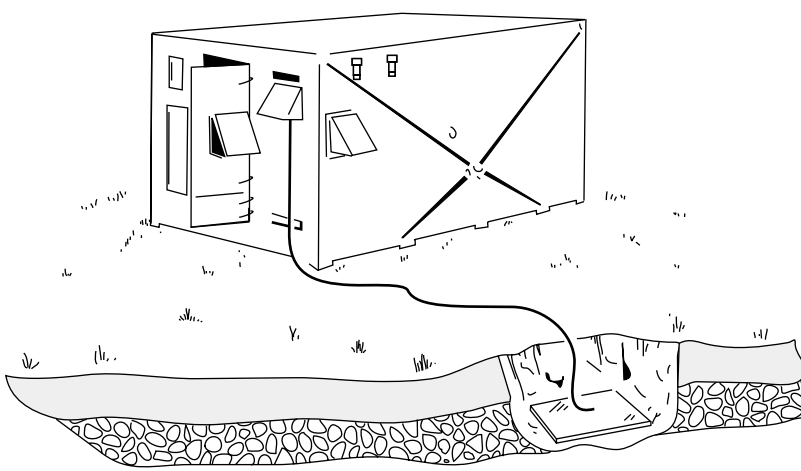


Figure 8–3. Ground Plate

Soil Conditions

823. Contact with the earth does not guarantee a good ground. The type of soil, its moisture content and its temperature all affect how well an earthing system works.

824. Soil is usually divided into two distinct layers. The first layer is topsoil, normally dry and loosely packed, and is a poor conductor of electricity. The second layer is subsoil, generally tightly packed and retaining moisture, and thus providing the best electrical ground.

825. Wet soil passes electric current more efficiently than dry soil and makes the earthing system work more efficiently.

Use of Multimeter

826. If available, use a multimeter to check the earthing system in the following manner:

a. Set the multimeter for AC voltage.

b. With the power on:

(1) place the red lead on the equipment metal, and

(2) place the black lead on the ground strap.

c. A reading of up to 5 volts is acceptable.

d. A reading of over 5 volts indicates a poor earth.

Safety

827. The procedures outlined in this chapter should assist in solving earthing problems. Lack of equipment earthing, or improper earthing, can result in personnel injury and equipment damage. Remember to earth all equipment and check that the earthing is effective.

CAUTION
First earth the equipment and check it